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VISIBILITY CHARACTERISTICS OF TERRAIN AND THEIR EFFECTS ON WEAPON-SYSTEM PERFORMANCE

The Army Terrain Task Force

MARCH 1980

U S ARMY MATERIEL SYSTEMS ANALYSIS ACTIVITY
ABERDEEN PROVING GROUND, MARYLAND 21005

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This study reviews the results of several experimental efforts each of which estimated the "intervisibility" which existed between elements of attacker and defender armor forces. It was determined that discrepancies among the results of those efforts may be attributable to differences in the definitions of variables being measured, methods of analysis employed and the terrain on which the exercises were performed. A proposed set of definitions of terms pertinent to the intervisibility area are provided.

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VISIBILITY CHARACTERISTICS OF TERRAIN AND
THEIR EFFECTS ON WEAPON-SYSTEM PERFORMANCE

I. INTRODUCTION

A. Background.

The effects of terrain and environmental features on military combatants' capabilities to detect, identify, and destroy their enemies has been of major concern since the origin of man. As the power and sophistication of weapon-systems has increased, providing higher speeds, longer ranges, electromagnetic sensing, and in-flight guidance of munitions, the importance of terrain effects has increased markedly. Today they impinge directly on every aspect of military weapon-system planning and design, training, battle tactics, and strategy.

Various studies to learn more about the causes and nature of these effects and to derive quantitative measures of them have produced numerous seemingly conflicting results. A major point of concern emanates from attempts to determine the relationships between terrain choppiness and what has commonly been called sensor-target line-of-sight (LOS) or inter-visibility (IV). In World War II, most hits on advancing forces occurred just after they first broke cover at distances in the neighborhood of 700 meters. This not only put targets within the defenders' weapon ranges, but made it very unlikely that additional cover could be obtained which would be effective against the high speed munitions then in exclusive use. With today's weaponry capability, however, targets can be acquired and munitions delivered out to several thousand meters. At these distances, terrain and environmental features can continue to intermittently mask the LOS thus preventing effective weapon delivery especially for relatively slow missiles requiring continuous in-flight guidance. The several massive efforts which have been made over the last two decades to study the modern battlefield, though well-conceived, have raised more questions than they have resolved. The terrain-effects issue was brought into clear focus with the publication of the results of HELAST II in July, 1973, which indicated, at least for the terrain involved in the study, relatively large numbers of short periods wherein an attacker alternated being in-view and out-of-view of a defender. These results had not been found in earlier studies such as TETAM.

What caused these differences in results? Were they due to experimental factors, to differences in the terrains involved, to specific pathologies, to lack of tactical realism? Is there really loss of contact, cover, or concealment? If so, for how long, with what frequency, and with what variations with range? What are the implications regarding types of weapons, types of munitions, sensors, weapon ranges, tactics, and strategies? Finally, what should be done next, and what resources are required to proceed?

Getting answers to these questions is obviously a necessity. Therefore, in April 1977, Mr. David C. Hardison, Deputy Under Secretary of the Army for Operations Research, initiated plans for an Army Terrain Task Force to examine the existing studies and attempt to discover the basic truths in what has been done, the causes of conflicting results, and the implications relative to military planning and development. Recommendations for courses of action, including guidelines for future studies and field exercises, would then be formulated. The task force was to represent all of the major sources of the necessary expertise available in the Army. The task force chairman, however, was to be independent of the Army OR community to help maintain balance and perspective in the analysis and resulting recommendations.

B. The Army Terrain Task Force.

The Army Terrain Task Force was called together by Mr. Hardison on 19 July 1977. The organizations represented were CACDA, TRASANA, HEL, and AMSAA. Dr. Albert B. Bishop, then a consultant to the Army Scientific Advisory Panel, had accepted the role of chairman. A list of task force members is given in Appendix A.

The basic charge given the committee was essentially to answer the questions stated above. An additional item included in the charge was to examine the use of digitized terrain information to construct computer experiments to alleviate the need for extensive field experimentation. Questions of importance include: (1) Should the computerized battlefields be models of sections of real terrain or fabricated to contain specified combinations of features? (2) What resolution is required to adequately represent terrain effects for study purposes? (3) How should environmental and man-made objects be handled?

After considerable discussion of potential terrain interactions with the performance of various aspects of the task of defending against an armor attack, the following list of basic concerns was formulated to guide the initial study effort:

(1) Definitions of "Intervisibility" and related terms;

(2) First sighting range and its relation with terrain characteristics;

(3) Periods of "Intervisibility" and "Nonintervisibility" and their relations with terrain characteristics; and

(4) Effects of human-response factors on each of the above.

The following plan of attack was then adopted:

(1) Obtain the available data which pertain to the issues cited.

(2) Examine these data for:

(a) Contributions

(b) Gaps

(c) Inconsistencies

o Internal to a particular study

o Between studies.

(3) Examine the implications relative to:

(a) Weapon-system design

(b) Tactics

(c) Training

(4) Determine courses of action to resolve the gaps and inconsistencies.

(5) Recommend studies and suggest test designs.

A list of those studies and reports felt to be most pertinent was compiled to serve as a beginning data base. This list is given in Appendix B. The treatment of each of the above issues in appropriate studies on this list was determined and reported upon at the next meeting, held at CACDA on 31 August 1977.

This review revealed considerable diversity of experimental method including fundamental differences, even within studies, in the basic definitions of intervisibility, line-of-sight, and related terms. The need for a standard, universally applicable set of definitions was, therefore, deemed a necessity before any meaningful comparison could be made, not only among study results, but also in the evaluation of approaches and methodologies. In fact, the term "intervisibility," with its implication of simultaneous two-way visibility, was felt to be completely inappropriate as a useful descriptor of any military situation. It is used in Chapter II of this report as a convenient generic term to refer to the general topics of LOS, visibility, etc., and is not used thereafter.

As a result, the task force effort proceeded on three fronts:

(1) Review and critique of the reports of the three studies most directly responsible for the current controversy:

(a) TETAM (CACDA and CDEC)

(b) HELAST II (HEL)

(c) STAGS (CACDA and HEL)

(2) Formulation of precise, universally applicable definitions of such terms as line-of-sight, visibility, detection, recognition, identification, and engagement.

(3) Terrain description:

(a) First sighting distance (definition, how to measure it, factors which affect it)

(b) Periods of "in-view" and "out-of-view" (definition, effect of range, intercorrelations)

(c) Real vs. idealized terrain (pros and cons of each, categorizations of battlefields, guidance for use in terrain studies)

Initial results were discussed at the 3-4 October 1977 meeting at Ohio State University and further developed at a meeting on 26-27 October 1977, also at Ohio State. During this period the evaluation of past work was extended to provide coverage of Chinese Eye, Lost Horizon, and, at least by inference, the NATO Range Study.

At the conclusion of the 26-27 October 1977 meeting, assignments were made regarding final write-up of the various sections of the report. Most of these were completed within a month and forwarded to Dr. Bishop for compilation of the first draft of the report. It so happened, however, that Dr. Bishop's term of appointment with the ASAP terminated in November 1977, and Mr. Hardison suggested a delay in further activity until new contract arrangements could be worked out. This was finally accomplished in September 1978, and the Task Force met 18-19 September at Ohio State to discuss the first draft and formulate changes. It was agreed to expand the analysis and discussion of the data, its quality, interpretation, and implication. A second draft was compiled which, after minor modification, became the final report.

C. Report Format.

In Chapter II of this report, the methodologies used and the results obtained from TETAM, HELAST II, STAGS, Chinese Eye III, Lost

Horizon, and the NATO Range Study are discussed and critiqued. A discussion follows of the implications of the findings from each study relative to the design of future experiments.

A set of definitions derived by the task force is presented in Chapter III. Although further improvement may be desirable to provide a completely precise, universally applicable set, the task force feels that those definitions presented constitute a major step toward the ideal and a step of sufficient magnitude to be useful in accomplishing the task at hand. Furthermore, these definitions will be the ones intended when the terms line-of-sight, visibility, etc., are used in Chapters IV, V and VI.

Chapter IV is a summary and evaluation of the data collected. The implications of the findings with respect to weapon system effectiveness are discussed in Chapter V. Also included is a summary of additional work required, which includes a discussion of the use of idealized versus real terrain. Chapter VI contains the task force's conclusions and recommendations.

II. REVIEW AND CRITIQUE OF PAST WORK

This chapter summarizes and critiques six of the more pertinent studies which involve the effects of terrain on the defense against armor attacks. Each is covered in its own section. Each such section includes a summary description of the study, a critique, a statement regarding the usefulness of the results, including both the methdology and any numerical results, and the implications for the design of future experiments. The studies are, in the order of their presentation:

Section	Study
A	TETAM (CDEC)
B	HELAST II (HEL)
C	STAGS (HEL and CACDA)
D	Chinese Eye III
E	Lost Horizon (bound in separate classified annex)
F	NATO Range Study

4. TETAM

TETAM Experiment 11.8, Phases IA, IE, IL, U.S. Army Combat Developments Experimentation Command (CDEC), 1972

1. INTRODUCTION

The most extensive empirical terrain visibility data base accumulated to date is TETAM, Phases IA, IE, and IL (Tactical Effectiveness Testing of Antitank Missile Systems 11.8). In 1972, the Combat Developments Experimentation Command (CDEC) conducted visibility measurements on a total of 16 sites in both the US and Federal Republic of Germany (FRG). The four US sites were located at Fort Hunter Liggett, California (designated sites 1L and 2L). The 12 remaining sites were in the Federal Republic of Germany. Five sites in Fulda and one site near the Hohenfels Training Area (designated sites 1F-6F) and six sites in the North German Plain (designated sites 1B-6B) were selected. The FRG data were collected in April through June 1972, and the HLMR and Fort Lewis sites were measured in September through December 1972. These data have been used (and are currently being used) in many models to analyze, evaluate, and simulate weapons systems performances; and the results have had and are having significant impacts on decisions made on weapons development and fielding. Thus, the importance of accurate intervisibility data cannot be overestimated.

a. Description of Test and Experimental Methodology.

(1) Purpose. The stated purpose of the experiment was "to obtain data on the frequency and segment lengths of line of sight (intervisibility) between advancing armor units and emplaced antitank missile systems (ATMS)."

(2) Methodology. A short description of the methodology or experimental procedure follows.

(a) Site Selection. The 12 FRG terrain sites were selected by CDEC planners. They were located in areas that have been traditional invasion routes through Germany. Five of the sites chosen were in the Fulda Gap area, one was located in the Hohenfels major training area, and six were in the North German Plain, between Hanover and Hamburg. The question of how well the chosen sites represented the general area was addressed in the TETAM report by the following comments:

> There is no scientific proof that the six sites used in each area were in fact representative of the general areas in which they are located. It is unlikely that attacking armor forces would actually be encountered on four of the sites

(3F, 5F, 5B, and 6B); in only two of those sites (3F, 5B) however, were tank trails forced over a majority of terrain which tanks could not traverse.

(b) Defensive position siting. On each 2x5 km terrain site the most defensible terrain was selected by team members. An infantry officer was given the mission of organizing a simulated area defense on that terrain incorporating 30 or 36 antitank missile positions. At each ATM position chosen a set of three tri-colored wooden panels was erected facing the far end of the site. Each ATM panel was identified by a large numeral or letter and also by a 1'x12' target cloth "V" (for location by aerial photography). The top colored stripe (i.e., blue, 44" in vertical dimension) on each panel represented the height above ground of a Shillelagh missile system; the second stripe (red, 28"), the height of a TOW M113 mounted; and the bottom stripe (yellow, 44"), the height of a TOW or DRAGON (ground mounted). Each position was map spotted by the infantry officer.

(c) Armored vehicle approach paths. Ten armored vehicle (tank) approach paths were laid beginning at the end of the site away from the defended terrain. Ten tank commanders were given the mission of selecting and delineating the paths that they would follow in a tank if they were advancing using rapid approach threat doctrine. Paths on 11 of the 12 terrain sites were selected by tank commanders on foot since maneuver rights could not be obtained in these sites. Tracked vehicles were used on site 6F (Hohenfels major training area). Tank commanders were instructed to take the most direct route through the site, commensurate with physical limitations of a tank.

> As a tradeoff of tactical realism for experimental completeness, tank commanders were instructed to go through obstructions (towns, heavy brush, forest), which a tank would not ordinarily go through, rather than skirting them. This was done to cover the site more thoroughly with viewing points. Paths were terminated on one side of the obstruction and began on the other side, where visibility was likely to exist.

Moving with the tank commander, a four-man detail marked each path at 25-meter intervals; these points were called viewing points. Every other viewing point was marked with a 1' x 6' target cloth "X" for location by aerial photography.

(d) Data Collection. A data collection team, called "Battelle Walkers", moved along each path, stopping at every 25-meter interval stake marker to take two readings. The first was from 7 feet high (turret height of a tank) and the second from 4 feet high (hull height). Using unaided eye, binocular, or telescope (choice left to the individual) one team member scanned the defensive

front (left to right), identifying the lowest color on each panel that could be seen. If none of the panel was visible, a notation for nonvisibility was recorded. Obscuration was categorized as vegetation, landform, manmade objects, and unknown. The report comments:

> The project team was aware of the purposes for which Phase IC information was being collected; field determinations were therefore made to insure that data collected would reflect <u>intervisibility</u> as it existed in presenting opportunity to <u>engage</u> with ATM.

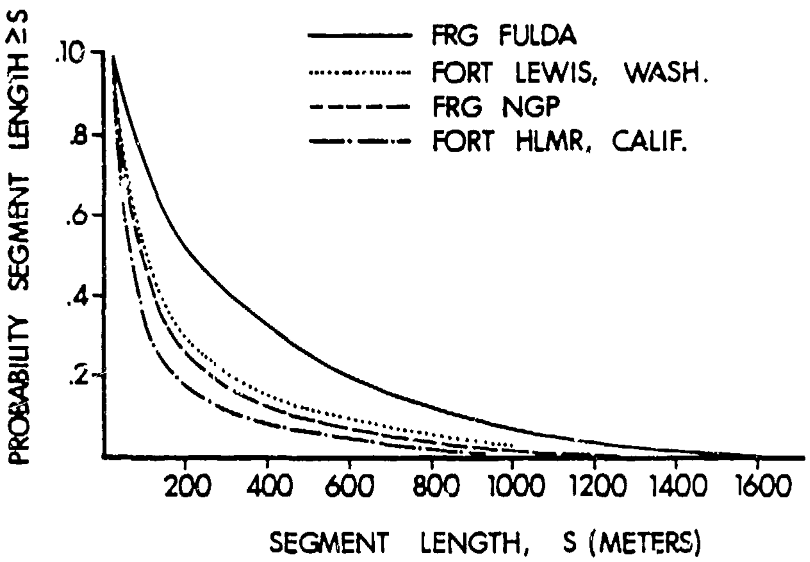
(e) US sites. Similar procedures were followed in the US on HLMR and Fort Lewis sites.

b. <u>Results and Analysis</u>. The results and subsequent analysis of the TETAM data generally focus on the visible segment length distributions (mean and standard deviation), the expected number of LOS initiations per ATM per path, the probability of LOS (total number of ATM-path stake pairs with LOS divided by the total number of ATM-path stake pairs), and the causes by percent for loss of LOS. Figure II-A-1 displays a set of summary statistics used to represent test results. They are taken from the CACDA TETAM analysis. CDEC published data results and analysis are somewhat different and show slightly longer visibility segments. The differences are in large part due to differences in aggregating results for analysis. In general, the TETAM results indicated shorter segment lengths and less LOS than had previous studies (NATO Range Study and Lost Horizons). In comparison with later experiments (HELAST II, STAGS), the TETAM results show in general much longer segments. Distributions of opening ranges derived from the TETAM data have not appeared in open literature.

2. CRITIQUE

a. <u>Methodology</u>.

(1) Overall tactical considerations. One of the principal areas of concern is in the tactical context and implementation procedures used in the test. Although the "tactically unsound" argument is often used by the tactician in defense against the onslaught of the statistically inclined ORSA, in this case the criticism may be justifiably warranted, particularly in the selection of tank approach paths. The paths chosen were not always constrained to be tactically realistic and/or subject to tank mobility constraints. In many cases tank paths were chosen that entered and exited from nontrafficable forested regions. Thus, the paths did not represent continuous tactical approach routes. Proper use of cover and concealment was in effect ignored, together with the continuity of the tank paths. Although the rapid approach tactic was being



STATISTICS

TEST SITE OR AREA	NO. INITIATIONS PER ATGM/PATH	P_{LOS}	MEAN SEG LENGTH (m)	S.D. SEG LENGTH	LOSS OF LOS LAND	VEG	CUL
FULDA GAP	2.84	.390	367	358	55%	30%	15%
NORTH GERMAN PLAIN	2.73	.181	183	254	21%	77%	2%
HLMR	6.36	.283	133	207	15%	83%	2%
FORT LEWIS	3.88	.421	190	269	~0%	84%	16%

Figure II-A-1. Summary Statistics of TETAM Visibility Data.

represented, a review of the sites and associated trail overlays illustrates that the immediate concern was to spread the 10 paths apart so as to cover more uniformly as much of the terrain site as possible. In effect this would tend to decorrelate paths further from cover and tactical realism. Even with this approach, vegetation was in nearly all sites the predominant cause of LOS interruption. A more realistic tactical threat approach would therefore imply a greater use of cover and, therefore, a closer correlation of paths with near vicinity cover. Thus, since first sighting distance and other LOS and visibility characteristics are closely related to the quality of the tactical use of the terrain, the values obtained in this study could contain significant errors.

(2) Density of defender positions and paths. The selection of 30 to 36 defender sites versus 10 attacker paths was clearly a tactical error. Real world conditions usually dictate a threat numerical advantage of at least three, hopefully five, to one before attempting an attack. This in itself should reflect somewhat as to the relationships between weapon/target densities and target exposures. From the point of view of maximizing visibility, the net effect is to underoptimize the "average" defender position. The spreading of the threat paths over the entire area further confounds the results. A larger threat force, 20 to 30 paths (tactically chosen), together with a smaller defender force, 10 to 15, would have allowed a more realistic tactical situation to be portrayed. The panels representing the defender positions were too frequently placed on the military crest of the defensive position to facilitate their being seen by the data collectors. Any actual ATM positions located in defensive positions would utilize hull defilade firing positions or concealed positions considerably forward of or behind where the panels were located, and would thus have a different view of the battlefield. Also, the use of differing height panels to represent different weapons systems is questionable. In fact, it is difficult to distinguish a weapon system (other than helicopters) by its height above ground if it selects a tactically realistic position. Tanks and TOWs, for example, select their defensive firing positions using differing criteria, both seeking to minimize their exposure to enemy fire.

(3) Measurement resolution and definition of visibility. The next most critical aspect of the TETAM experiment impacts tremendously on the interpretation of results and traces directly to the definition of visibility and measurement resolution used.

(a) Visibility definition. Visibility was defined to exist if the data recorder at a 25-meter marker along the path could see any portion of the ATM panel and if, in his judgment, the intervening vegetation, cultural, or land mass obstruction(s), if any, were not severe enough to prevent engagement of a tank target on

the path. Primarily, the restricting condition was based on warhead penetration of the intervening vegetation without premature detonation. In those cases where the tank path recording location was blocked by local vegetation, the recorder was allowed to adjust (i.e., move a small distance away from a tree branch, clump, etc.) in order to obtain the intervisibility measurement. This localization was intended to allow for partial obscuration of a tank from the ATM. This resulted in the sampling location being changed because of feedback from the condition being measured. Such a local optimization tends to introduce a lower limit on the size of an interruption or obstruction to LOS that would be included in the sample. Thus, small branch, leaf, or tree trunk clutter near the target in effect could be ignored to the extent the judgmental definition of the recorder did not consider it as preventing an ATM engagement.

(b) Measurement resolution. The measurement technique implied a static measurement from two observation points (4 feet and 7 feet high) at each 25-meter marker along the tank paths. The interpretation that is generally applied to the resulting data treats the condition measures at each point (i.e., visible or nonvisible) as an attribute existing along the entire 25-meter segment. Using this assumption, successive 25-meter segments along the paths are combined into "continuous" intervisible and nonintervisible segments, and the resultant density distributions of segment lengths are formed. (This is the technique that results in the values shown in Figure II-A-1 and was used to arrive at the means and standard deviations shown). Clearly then, the results are an approximation to rather than a measurement of continuous visibility. A better approach to determine the required measurement resolution necessary to achieve an estimate of continuous visibility (or lack thereof) would be to base the sample spacing along each path on the dimension (minimum presented horizontal spread) of the target tank vehicle. Then at least, the discrete sampling technique, combined with the same visibility definition, would allow a reasonable extrapolation of segment length distributions.

b. Data Interpretation and Validity of Reported Results.

Based on the above described measurement procedures, the following qualifications should be applied to the TETAM statistical parameters.

(1) Probability of line of sight (P_{LOS}). Subject to the definition of LOS specified, this statistic should be quite close to the value that would be estimated using a "continuous" measurement technique. However, tactically the TETAM results may be misleading

since they are dependent on variations in defender siting and approach route selection resulting from a questionable tactical scheme. Thus, higher resolution measurements are not expected to change results significantly if definitions and tactics are kept constant.

(2) Expected number of LOS initiations. This statistic is extremely sensitive to resolution and visibility definition. Obviously the TETAM data must be an underestimate if any LOS breaks less than 25 meters exist. How much is unknown. Some preliminary work on resolution comparisons show that if measurement resolution were 5 meters, then the number of segments could well increase by factors of 2 to 3.

(3) Duration of LOS segments. Just as the number of initiations is underestimated, the durations are overestimated since the product of the expected number of initiations and the average visible segment length duration is proportional to the P_{LOS} statistic, which is relatively stable. In effect, this means the three "statistics" should not be treated as independent.

(4) Fractional cover. The primary reason for loss of LOS was reported to be vegetation in the majority of data except for the Fulda sites, where landforms were predominant. This is the only clue we have in attempting to extrapolate the test data. If the predominant reason for loss of LOS were due to landform, and if landform surface height variations over distances of 25 meters are sufficiently small, then the TETAM sampling procedure may be quite close to higher resolution measurements. On the other hand, if the LOS loss is primarily due to vegetation, then the corresponding height fluctuations of the vegetation over 25 meters would dictate the impact. Fluctuations of vegetation height, location, and density can easily be substantial. With such fluctuations, the TETAM results would be significantly altered in the direction of shorter visible segments.

3. USES OF RESULTS

a. The TETAM visibility experiments represent an extensive and usable data base if properly qualified and understood. However, it is not a high resolution data base and should not be used to "predict" or represent continuous visibility in problems involving fractional target coverage. Comparisons of weapon systems dependent upon rate of fire, missile/round time of flight, weapon observer tracking, and in general, other parameters closely related to fractional or intermittent cover are not supported by this data base. The data are, however, quite applicable when addressing problems where precise time or space resolution is not required. For example, "How many potential kill zones of 200 to 300 meters duration exist between 2 and 4 kms in Fulda type terrains versus NGP terrains?", is a reasonable TETAM data base problem, again subject to the previously mentioned tactical constraints.

b. It is unfortunate that models and simulations that use the TETAM data for comparing relative effectiveness of guns versus missiles apparently ignore the fact that the TETAM intervisibility data pertain only to engagement with specific missiles under a very restricted set of assumptions, which are not applicable in general to other weapon systems and target engagement processes.

c. Since the basic tank paths were determined by persons operating independently of each other, not only is the actual route selection itself in question, but the possibility of assuming any time coordination between the various moving elements is prevented. Thus, the whole section of the TETAM report dealing with multiple target intervisibility to a single firer is questionable.

4. IMPLICATIONS FOR DESIGN OF FUTURE EXPERIMENTS.

a. The detailed analyses of the TETAM data and the subsequent problems in which analysts have attempted to use the data are severely constrained by three conditions, namely, the underlying tactical conditions, the measurement resolution, and the visibility definition. The first lesson to be remembered is never violate tactical realism for the sake of "experimental completeness", etc., without first demonstrating that such modifications are immaterial. Second, specify precisely definitions of the terms to be used and, third, field checks should be made to insure that the measurement technique will produce the data described in the definition.

b. On force multiple intervisibility, the threat element paths and dynamic time sequence must be generated as a tactical unit. Individual route selection is not adequate.

c. Visibility is a two-way problem. Reversed measurement is not adequate. Likewise, the location of intervening mask or partial obstruction relative to the observer/target location is essential for detailed interpretation. To date mask locations have not been recorded in visibility experiments.

B. <u>HELAST II</u>

<u>A Field Study on the Effects of Mobility/Agility on Target Presentation and Defender Reaction</u>, US Army Human Engineering Laboratory (HEL) Technical Memorandum 12-73, July 1973.

1. INTRODUCTION

The HELAST II Experiment was conducted at Fort Knox, Kentucky, in September and October of 1972. The effort was conducted in three phases, the objectives of which were:

Phase I - "to develop experimental techniques to assess gunner tracking performance on a more realistically moving target than currently used in most research, development and testing";

Phase II - "to describe in detail the target presented by a tank maneuvering under tactical type conditions"; and

Phase III - "to measure how increasing the mobility/agility of target vehicles might affect the fire-engagement behavior of stationary gunners."

While Phases I and III are certainly of general interest, Phase II deals with the intervisibility area in particular and so our comments will be restricted, for the most part, to that phase.

The Phase II test data were collected by personnel located at 5 defender positions, who were observing vehicles with various mobility characteristics moving along 7 "tactical paths".

The defender/viewer positions were chosen without tactical considerations in mind. That is, those positions were chosen to optimize the defender's view of the vehicle paths and most were completely in the open; cover, concealment and acceptable escape routes were not provided.

On the other hand, the target vehicle paths were chosen to represent various tactical movements. For example, four of the paths could be described generally as attacking the defender positions, one represented a crossing target, and the final two were laid out to represent a vehicle emerging from the woods, being fired upon, and returning to the cover provided by the woods.

All seven paths were located in a single region of Fort Knox just south of St. Vith's Ridge, but each one was designed independently of the others. The paths were laid out so that each contained several "halt points", i.e., locations at which the attack vehicle was completely out of view of all defender positions. Table 1 of the project report shows the lengths of the path segments between halt points. Four of the seven courses were less than 400 meters in total length.

During the conduct of the experiment, a color coded tank was moved along each path, and the intervisibility status of that vehicle to each defender position was determined in two ways. First, the tank was moved to "stop points" located at 25 meter increments along the attack vehicle paths. At each of these points the tank was photographed, in color, from each of the defender positions. Secondly, the tank was moved over each course at "as close to 5 mph as possible" while gun cameras at each firing position made continuous film

records. These data collection methods provided the intervisibility information sets which were compared in the analysis of Phase II.

2. CRITIQUE

Two major contributions were made by HELAST II. The first was the recording of visibility data from the defender position to the attack path instead of vice versa as was done in TETAM and earlier studies. Since visibility involves more than point-to-point LOS (see Chapter III of this report), the direction of viewing is of vital importance.

The other major contribution was the use of movie cameras to obtain continuous records of target advances to serve as a check on the discrete static recordings to which previous studies had been limited. Comparison of the 25-meter resolution with the continuous film data indicated that on the whole the discrete data generated significantly longer visible paths than did the continuous observations.

Conversely, several questions can be raised concerning the design of the HELAST II experiments and hence their results. The independence of the attacker paths necessarily precludes the collection of meaningful multiple-target visibility data. The limiting of path locations to a single region raises questions about whether an adequate sampling of terrain was obtained to permit the results to be generalized. This is especially pertinent since it was found that it seems to be mainly vegetation "which serves to interrupt the gunner's view of the target, not vertical terrain masking," and the vegetation at Fort Knox is very different from that found in more likely combat sites.

The shortness of the paths raises doubts as to whether enough data could be collected on them to draw any firm conclusions about the intervisibility characteristics of the St. Vith's Ridge area, let alone enough to make generalizations to more probable combat areas.

It was reported that the "leaps-and-bounds" technique of vehicle movement used on all the paths constrained all halt positions to be completely out of view of all defender positions. Although these halt points were identified after the paths had been laid out with the objective of enhancing tactical realism, nevertheless, they could tend to shorten the length of in-view periods thus increasing the number of transitions between in-view and out-of-view states than might otherwise be expected. This could certainly explain differences with TETAM and other results.

Any analysis of experimental data must of course take into account the errors inherent in the control of experimental conditions

and data collection. In the collection of the HELAST II intervisibility data, the intervisibility status is assumed constant over 25-meter path segments in the discrete case, and that status is determined by whether IV does or does not exist at the initial point of the segment. Clearly the goodness of this approximation depends upon the characteristics of the terrain being evaluated as well as the fineness of the measurement resolution. In the continuous mode, the color coded tank moved along each course at "as close to 5 mph as possible". Yet no data are provided to assess the variability of tank speed - and hence the length of intervisible segments - during the "continuous" phase. The impact of these problem areas cannot be assessed but should be kept in mind when reviewing the test results and conclusions.

3. USES OF RESULTS

a. Methodology

Two methodological contributions of HELAST II were mentioned in the last section. These were (1) the recording of the data from the defender positions toward the attacker, and (2) the collection of continuous visibility data. Both led to interesting results which require additional study. The directionality of visibility-related phenomena is heavily supported by both logical considerations and the need for tactical realism. The collection of continuous visibility data on film provides the basis for comparisons with discrete data of any desired resolution. Some further examination by HEL has already culminated in HEL TM 11-74, "The Effects of Measurement Resolution on the Descriptions of Target Visibility." The findings of that report led to the "continuous resolution" laser data collection methodology used during the STAGS experiments, and will certainly be required for the evaluation of laser guided systems which will require intervisibility data as input. However, it should be emphasized that other locations could help relate resolution to a variety of terrain characteristics, thereby making it possible to specify acceptable resolutions for future field studies and be assured of obtaining high quality data without the need for expensive movie equipment.

b. Data Interpretation

There is enough controversy over just how representative of realistic combat areas the terrain and vegetation at St. Vith's Ridge is, and over the amount of data collected during HELAST II, to preclude the use of those results in analyses supporting important weapon system decisions. However, the measurement techniques, definitions of terms, and data collection procedures used in HELAST II, appear to be among the most realistic used in any experimental effort up to that time.

In general, there appears to be a tendency in those "intervisibility studies" to try to characterize the IV attributes of a particular terrain/tactical scenario combination, by the distribution of IV segment lengths. While this distribution is certainly an important indicator, it does not provide all of the information necessary for a system evaluation. For example, the distribution of nonintervisible segment lengths is also very important, as well as knowing whether there is any correlation between the lengths of adjoining in-view and out-of-view segments.

TOW, COPPERHEAD and HELLFIRE are all systems whose employment requires significant periods of IV, but which will tolerate breaks in LOS of certain durations. Thus a more complete analysis and characterization of test data are required from future efforts. Specifically, effort must be directed at answering questions such as:

(1) How can we characterize terrain and vegetation from an intervisibility view point?

(2) How do the IV characteristics at Fort Knox compare with those of more likely combat sites?

(3) Do the results found in HELAST II seem representative or pathological?

With these thoughts in mind, the first conclusion drawn by HELAST II was that "for this terrain structure and vegetation, tanks moving in a tactical type situation present enemy gunners with intermittent target exposures of brief duration."

Although the tactical realism of the defenders positions can be questioned, it seems probable that the choice of concealed positions with acceptable escape routes, etc., would have served only to decrease the intervisibility characteristics of those positions. The attack paths chosen do individually represent some variety of the tactical movements in which tanks are likely to become involved. However, the lengths of the courses and the ranges and frequency with which each type of maneuver was conducted, and how they compare with actual battlefield conditions could no doubt be debated.

Nonetheless, with the caveat that the results apply only to the terrain on which they were obtained and for the particular vehicle paths chosen, it would be hard to seriously quarrel with the HELAST II conclusion concerning short-duration, intermittent target exposures.

Perhaps the "surprise" associated with the publishing of the HELAST II intervisibility results was caused by their significant departure from the IV results of earlier studies such as TETAM. However, the results of that study may not be a good basis for comparison (see Section II-A on the Review of TETAM).

4. IMPLICATIONS FOR DESIGN OF FUTURE EXPERIMENTS

The implications of the intermittent nature of the exposures of advancing targets was discussed above in subsection 3b with respect to the effects on such devices as TOW, COPPERHEAD, and HELLFIRE. Obviously these devices must be tested under various conditions of in-view and out-of-view path segment distributions. An associated item of basic importance is to determine correlations of segment lengths in various types of terrain. Such correlations and effects on the capability of various weapon systems to successfully engage moving targets is addressed in Chapter V.

Measurement-resolution effects on the determination of in-view and out-of-view segment lengths was covered in subsection 3a. Knowledge of acceptable resolutions for various types of terrain would certainly enhance both the effectiveness and the economy of future experimentation.

An additional finding, not previously discussed, is that "slight changes in observer position can result in large changes in those portions of a target path which are visible." This finding, also noted in the Lost Horizons tests, emphasizes the desirability of measuring intervisibilities from the defender position and points to the need for more than a single replication of data collection on the same piece of terrain. That is, two or more sets of defended positions and attack paths and multiple runs over each path should be used in assessing the characteristics of any single piece of terrain. This point should be considered in future experimental efforts.

This finding also has another important implication. Several commonly used computer combat simulations (e.g., AMSWAG, CARMONETTE, DYNTACS) are played on digitized terrain. In these simulations, engagements with direct fire weapon systems can occur if the target is within the maximum range of the weapon and if "LOS" exists. The existence and duration of LOS in these models is deterministically assessed by computations on the digitized terrain data base. (DYNTACS does allow superposition of some microterrain features as random variables, but does not directly provide inter-segment correlations or calculation of durations of interruption of LOS.) However, as pointed out, slight changes in an observer position can significantly alter the IV characteristics of that position. Studies have also been performed which show that the "kill scoreboards" and final outcomes of simulated battles can be completely changed by small changes in defender positions and attacker path (see: Investigations of the Variation of Combat Model Predictions with Terrain Line of Sight, Farrell, R. L., and Freedman, R. J., Vector Research, Inc., Report No. AMSAA-1, FR75-1).

With these results in hand, one wonders about the utility of models which treat intervisibility deterministically, especially in

the evaluation of those systems, e.g., TOW, COPPERHEAD, HELLFIRE, whose effectiveness is so sensitive to the IV characteristics of the terrain immediately surrounding their deployment. In those cases it seems that a stochastic treatment based on appropriate empirical data of IV would lead to more believable and repeatable results.

C. STAGS

The Influence of Tactics, Use of Terrain, and Measurement Techniques on Apparent Target Behavior, US Army Human Engineering Laboratory (HEL) Technical Memorandum 23-77, July 1977

and

STAGS Intervisibility Study, US Army Combined Arms Combat Developments Activity (CACDA) Technical Paper TP 2-77, February 1977

1. INTRODUCTION

The data described in the two subject reports were collected during the Swedish S-Tank Agility/Survivability (STAGS) Evaluation, conducted at Fort Knox, Kentucky, and Fort Bliss, Texas, from November 1975 to March 1976. The general objective of this field experiment was to describe the way an attacking tank, when operating as a member of a tactical unit, appears as a target to defending gunners.

More specifically, the experiment utilized different terrains, attacker tactics, defender weapon types and techniques of measuring "intervisibility" in an attempt to answer questions such as:

a. How do each of the above factors influence the targets visible to a defending force?

b. What are the times and distances along its path that an attacking tank is visible to various defenders?

c. What is the total time along its course that an attacker is visible to one or more of the defenders?, and

d. What is the frequency and duration of simultaneous defender visibility to multiple targets?

2. CRITIQUE

The HEL and CACDA reports were based upon the same field experiment. Hence, there were necessarily some similar analyses and reporting of results, especially in the areas concerning the discrepency between visual and laser[1] "intervisibility" data and the effect of tactics and terrain on the measured "intervisibility" information.

Aside from these common areas, the HEL analysis was concerned with a comparison of the differences in visibility from ground mounted and simulated helicopter hover firing positions. The CACDA report, on the other hand, presented a great deal of information on two aspects of multiple visibility, i.e., the number of times when one defender position had visibility to multiple targets and the numbers of times when multiple defenders had visibility to the same target.

While it does make sense to discuss those areas separately, there are aspects of the experiment, which, being common to both reports, can be reviewed in the context of both reports. The following paragraphs discuss therefore, (1) the selection of test sites and (2) the measurement of laser visibility (termed intervisibility in both reports).

a. Test Site Selection

It is stated in the HEL report that "test site selection was deemed critical, because of the desire to consider the usual and normal situations rather than the unusual or bizarre." Forts Knox and Bliss were chosen therefore since "Fort Knox (is) considered as representative of the terrain and vegetation found in portions of Northwestern Europe, and Fort Bliss of that found in some desert areas." Two test sites were chosen both at Forts Knox and Bliss. The choice of the Fort Knox sites was based upon the following factors:

(1) The waterways Experimental Station indicated that the vehicular trafficability of those areas very closely matched that found in the Fulda area of Germany;

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[1] In the STAGS study, laser designation was the only EO system employed. Therefore, even though the original reports have sometimes referred to electro-optical systems in general, the experimental results do not cover the spectrum of EO devices, so in this report the term laser will be used exclusively.

(2) The sites chosen provided the longest field of view of any sites available; and

(3) Certain experienced Army Officers felt that the chosen sites were quite representative of "German Terrain".

The choice of test sites is, in fact a critical point, because the basis of recent questioning of the general applicability of the results of these two reports is that the Fort Knox terrain, and in particular its vegetation, is significantly different from that found in West Germany. Hence the objective of choosing "represent-ative terrain" may not have been met in STAGS.

Thus, it appears that until we devise a method for objectively characterizing a piece of terrain as to its inter-visibility characteristics, the chances of alleviating current problems by additional similar experimental efforts seem very low indeed. For example, unless such a characterization is developed, how will the sites for future experimental efforts to affirm or deny the findings of this study be chosen; and how could we ever be satisfied that the entire distribution of terrain, as far as IV character-istics are concerned, has been sampled and the effects upon our newer weapon systems determined?

b. Measurement of Laser Intervisibility

At each test site, defender positions were chosen with tactical considerations firmly in mind. The attacking vehicle paths were determined by the coordinated movement of a platoon of tanks, using each of two attack tactics, rapid approach and bounding over-watch. During the platoon movement each tank marked its position at 10 second intervals by dropping numbered blocks.

After the paths had been established, a color coded tank traversed the path defined by each vehicle in the platoon, staying as close to 5 miles per hour as possible. "Target visibility data were collected from each of the defensive positions both visually (with an observer looking through a weapon sight) and photographically (by means of a gun camera). Additionally, five of the defensive positions at each experimental site were equipped with a wide angle (±17°) Laser Detector in order to determine when uninterrupted line of sight existed between a laser beacon mounted on the commander's cupola of the target vehicle and the laser detector located at the defensive position." (HEL Report, p. 9) The laser "intervisibility" data were collected in the hopes that they would correlate well with the visual data. Then, it was reasoned, the laser method would provide a relatively easy way of measuring visual intervisibility in future tests. It is well known, however, that the visual and laser data

differed significantly. That difference has sparked concern about the ability of our laser guided systems to operate in a battlefield environment.

While it has frequently been discussed, the placing of the laser beacon on the color coded target tank and the receivers at the defender positions has, to a large degree, confounded the results of this experiment, at least as far as laser guided weapons are concerned. For example, it is not clear that the laser IV information could be used in an evaluation of any system requiring laser designation of the target, nor is it clear that the laser and visual IV results can even be compared. These points will be expanded upon in the following sections but it seems that future test efforts, aimed at assessing laser guided weapon performance, should avoid this problem area. For assessing other weapons such as TOW or BEAMRIDER for example, the best test set-up is not immediately obvious and its definition would require a careful review of the evaluation methodology available for those systems.

In the following sections, critiques of the analyses performed and conclusions drawn by the HEL and CACDA Studies are provided.

c. Data Collection, Analysis, and Conclusions Drawn.

(1) Comparison of Visual and Laser IV.

Within these studies, visual IV was defined to exist whenever any portion of the target was visible to the observer. However, laser IV was by definition said to exist whenever a sensor, mounted at a defender position, received radiation for an uninterrupted period of at least 0.4 second.

With these definitions of IV in mind, the HEL report comments that while the average percent of path length visible to visual and laser observers were about equal, the mean length of in-view segments was greater for the visual observers than for laser receivers. While this is certainly true for the way IV was defined in this study, one can question just how meaningful such a comparison is. For example, the data might be more comparable if we were measuring visual IV from the observer to the laser beacon mounted on the tank. But the way the definitions were established in the study, we are measuring visual and laser IV essentially to two targets of completely different sizes, i.e., in one case the entire tank, in the other the laser emitter. Further, by having the laser beacon mounted on the target, we completely lose the contribution to IV which a laser designator would accrue simply by moving his energy spot to a location on the target which is not being obscured by terrain or vegetation.

Secondly, by mounting the emitter on the target we do not obtain laser IV data which would permit the evaluation of any laser

guided weapon, although useful information for other systems might be generated by such a method. System simulations of laser guided weapons require information such as the amount of energy reflected from the target and other sources of reflected energy, such as those caused by under or overspill. In this study, a terrain feature which caused a break in laser visibility, for even a significant time, might have little impact on the effectiveness of an incoming laser guided weapon if the obstacle were located close to the target, so that projectile trajectory deflection, due to the false target created by the obstacle, is minimal. The distance to the obstacle causing an interruption in LOS is also important in the evaluation of systems such as TOW.

Subliminal clutter is defined in the HEL report as "objects which intrude between an engaging gunner and his target, which may serve to obscure or partially obscure the target, but which are ignored or even undetected by the gunner." The concept of subliminal clutter is put forth as a "probable, rational explanation for the distribution of short intervisible segment lengths which were observed for the laser."

However, it does not appear that anything as sophisticated as subliminal clutter is required to explain the laser intervisible path length distribution or the difference between it and the distribution of visually in-view path segment lengths. Again the differences seem largely explainable by the definitions of laser and visual IV used in this study, and the measurement methods for estimating laser IV. For example tree trunks or branches could be sufficient to cause a break in laser IV, and yet if the target were not completely hidden from (visual) view, visual intervisibility would, by definition, still exist. If observers were instructed that visual IV would be defined to exist when an attack would be made, using a projectile with a very sensitive contact fuze--which might detonate even on extremely light foliage, then there may have been closer agreement between the distributions of in-view segment lengths.

This is not to say that the phenomenon of subliminal clutter is not a real concern, nor that its effects should not be considered in future efforts pertaining to the evaluation of laser systems. It is possible that subliminal clutter will present a significant problem to designators operating even at moderate ranges. However, the set-up for this experiment precludes the need for that phenomenon to explain the observed results.

That the CACDA and HELAST II analysis teams were well aware of the inherent differences between the visual and laser IV data, was reflected on Page 18 of the HELAST II report and on page 33 of the CACDA report. The latter states:

> The position of the laser source provided intervisibility status disregarding low ground cover but did not account for instances of high canopy cover such as that caused by trees where the lower part of the tank could remain visible. The use of a single laser source results in LOS measurement only to that point on the tank. Thus, parts of the tank could be visible to an observer but at the same time be considered out of LOS to the laser receiver.

(Note the use of the term "LOS", while the HEL report uses "intervisibility".)

In an attempt to reconcile the differences between the visual and laser IV data, CACDA employed filtering techniques. That is, breaks in "exposure time" of less than 2 seconds or less than 5 seconds were disregarded. The average exposure duration of these filtered data sets were then compared with the visual average for each terrain/tactic combination. It was felt that this filtering would reduce the problems associated with measuring laser IV to a single point source and bring the laser data into closer agreement with the visual.

However, the acceptability of this approach is in doubt because of the inconsistency of the results achieved by its use. For example, on the Knox East-West Course the 2-second filter yields agreement beween the two data sets (laser and visual IV) for the rapid advance tactic, but the 5-second filter is required for the bounding overwatch technique. On the Fort Knox North-South Site, a filter between two and five seconds produces agreement for both attacker tactics. On the Bliss Site 1--the visual and unfiltered laser data agree rather well, while in Bliss Site 2, a 2-second filtering is required. In summary then, the filtering approach does not provide a uniform way to reconcile the discrepencies between the two data sets. On this point CACDA states that:

> Some of the differences between the observer and laser data can be explained by allowing the laser data to have an error (filter size) of approximately one tank length. However, other discrepencies can only be explained by the additional error and judgement on the part of the observer.

The last portion of the preceding statement brings to light another interesting point. That is, that by the definitions provided elsewhere in this report, the STAGS experiment is actually comparing visual <u>detection</u> with laser <u>visibility</u>. While it is not believed that this <u>distinction</u> contributes <u>significantly</u> to the differences in the results, it is one which should be kept in mind.

(2) Ground vs Helicopter Visibility.

A portion of the HEL analysis was also directed to a comparison of the IV characteristics of ground and helicopter mounted systems. That report does indicate that a great deal of thought was given to the choice of the helicopter positions; and that, due to resource constraints, observation towers were constructed at those firing positions. It was from the towers then that the IV measurements were taken. However, one can question whether this kind of test set-up actually "plays" the helicopter as it would be tactically used in the field. For example, an attack helicopter (AH) may not always hover in a single position to detect, lock-on and guide a missile to the target. It is currently felt that a large part of the time a scout helicopter or ground based designator will detect a target, report the target's coordinates to the AH, and then either designate the target itself or hand the target over to the AH for autonomous attack (i.e., AH would designate the target itself). In any case, some feel that the AH might then move to a spot which would afford him a view of the target as well as some cover, concealment and an escape route. Therefore, it seems that by choosing a fixed position for the helicopter, from which he must view all targets, we are not taking the unique high mobility capabilities of the helicopter into account.

On the other hand, some feel that when used in a defensive role, the attack helicopter will carefully choose firing positions and repeatedly pop-up and fire from the same positions. In these circumstances, the STAGS test set-up is not unrealistic.

One conclusion of the HEL report then is that "there is no significant advantage in target IV accruing to an airborne weapon system, when using Nap of Earth (NOE) tactics, over an equivalent ground mounted weapon system." While this appears to be a rather strong conclusion from a limited amount of testing performed, if the second description of the way in which attack helicopters will be tactically used is true, then there may be some indication that the conclusion is warranted, at least for the particular terrain on which STAGS was conducted.

(3) Multiple Visual Visibility.

A major advantage of the STAGS experiment and associated data base over that of other "intervisibility" tests is the ability to regenerate the dynamic tactical movement of the tank platoon which was used to generate the attack paths.

There are at least two important uses of this multiple visibility type data. First, in the evaluation of weapon systems (TOW, COPPERHEAD) with significant time of flight or response times, the original target of the system may no longer be available for

attack by the time the weapon arrives in the target vicinity. Hence, in the evaluation of those systems, it will be important to know the visibility status to each potential target as well as the spatial separations of those visible at any time. With these data then, it can be determined whether or not it is possible to redirect the weapon to another target, which is at that time engageable by that weapon.

Secondly, these data are useful in comparing the effects of tactics, (rate of advance, use of cover and concealment, etc.) terrain and weapon types as to the opportunities which the defending force will have to fire on the attackers.

(4) Opening Ranges.

In its report on the STAGS experiment, CACDA presents data on the "range from defender to target at first LOS initiation." (Again note that what was actually measured was range to first detection). CACDA points out, however, that attacker paths at the Knox and Bliss sites were no longer than 2000 and 4500 meters, respectively, from the defender positions.

With these reservations in mind, CACDA points out that the range to first detection appears to be tactic independent, but highly site dependent. A two-way analysis of variance of the data presented supports CACDA's conclusion.

(5) CACDA and HEL Report Conclusions.

The CACDA report does not draw any major conclusions from the STAGS experiment. It does point out, in a summary section, that the visibility patterns of targets to defenders depend upon tactics, terrain, and defender position. They also caution readers that "intervisibility data from observers should be used very carefully." This is presumably due to the differences between the laser and visual data and that the latter should not be applied to the evaluation of laser guided weapons. Finally, CACDA states that it will conduct further analyses "to examine what effect the difference of target intervisibility recorded by a laser and an observer has on the engagement opportunities of specific weapon systems."

HEL, on the other hand, has drawn some rather significant implications from their analysis of the STAGS data. Those concerning the difference between laser and visual "intervisibility", subliminal clutter and the differences between the visibility from ground and air weapon systems have been discussed earlier. However, in light of concern over test site selection and laser measurement methodology, the practical value of the test results and whether or not they support the major conclusions of the report can be seriously questioned.

3. USES OF RESULTS

For the reasons stated previously, the laser IV data collected by STAGS cannot be used in the evaluation of systems which require laser designation. While the visual intervisibility data collected are of value, their utility is questionable due to the controversy over the "representativeness" of the terrain chosen for the tests.

Concerning the test methodology in STAGS, the laser equipment used in this effort may not be sensitive enough (or at least was not set to be sensitive enough) to collect data which would be of use in system evaluation. Specifically, at the rate at which the laser HELLFIRE seeker receives energy pulses, it is felt that if only a relatively few pulses in succession are missed by the seeker, decorrelation[1] will occur. Such a set of pulses could easily occur in slightly less than 1/2 of a second. However, for the equipment used in this test, loss of laser intervisibility occurs when radiation from the target is interrupted to a previously activated sensor for a period of at least 0.5 second. Hence, the equipment used in STAGS might not detect a break in laser IV which was significant enough to cause a decorrelation of the HELLFIRE missile. Even though some interruptions caused by temporary lock-on to intermediate objects would still allow subsequent lock-on to the actual target, problems of this sort must be avoided in future efforts whose goals are to generate data for system evaluations.

Previous studies, namely HELAST-II and HEL TM 11-74 entitled "The Effects of Measurement Resolution on the Descriptions of Target Visibility," have shown the pitfalls and incorrect results which accrue from obtaining visual IV data at 25 meters or greater increments along the target path. As noted earlier, STAGS visual IV data were collected continuously, and this methodology should be adhered to in future efforts.

4. IMPLICATIONS

The STAGS data show a difference between laser and visual intervisibilities. However, it should be emphasized that because of the atypical way in which the laser data were obtained (i.e., a laser beacon on the target and a detector at the firing position), it cannot be determined whether these differences are due to the test procedures or to such other factors as subliminal clutter. Therefore, it is impossible to conclude directly from these results the effect of laser, much less general EO, intervisibility on weapons performance.

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[1] At decorrelation the missile begins to act like a free flying rocket.

However, both the HEL and CACDA reports have raised enough concern over the visibility characteristics of laser and other sensing systems which might exist in battlefield conditions, and their implications on the utility of laser guided beam rider and TOW/DRAGON type weapons, to warrant a careful further examination of that subject.

Only moderate amounts of data were collected concerning the IV available from attack helicopter firing positions. Indications may be, however, that they do not enjoy significant improvements in IV over ground mounted weapon firing positions. If the justification for the attack helicopter depends heavily upon an increased visibility, then the finding of this report (i.e., no significant advantage in IV for airborne over ground weapons) should be tested with further experimentation.

5. ADDITIONAL ANALYSIS OF STAGS DATA

A further analysis of the STAGS data collected at Fort Knox has been completed and a draft report prepared by USAHEL. It should eventually appear as a HEL Technical Note entitled, "A Pilot Analysis of 'Stags' Intervisibility Film Data and its Implications for Future Assessments." Since it deals with several items of major interest to the Terrain Task Force, it is appropriate to discuss the findings here.

The data were obtained from a frame-by-frame analysis of the motion picture film taken from each observer position during the conduct of the STAGS intervisibility experiment. These are: (1) the resolution effects involved in the use of film data, (2) the percent of target exposed, (3) the type of obstacle causing loss of LOS, (4) the approximate location of the obstacle causing loss of line of sight, (5) presented target aspects as a function of attacker tactics, and (6) a comparison of results of analysis of film data with that obtained from visual data.

a. Summary of Findings.

1. The apparent visibility of a target is significantly affected by the measurement resolution, even down to time intervals as small as 1/8 second increments, as a result of clutter effects. While the determination of the existence of "line of sight" at such resolutions may have little or no effect on a gunner's visual performance (being largely subliminal in nature) the implications can be very significant for the performance of systems depending upon lasers and other types of electro-optics.

2. When "line of sight" is measured to a target, the definition of the required percent of target exposed, or visible, for "visibility" has a significant influence upon the lengths of visible segments. That is, there is a significant change in measured visible

segment lengths if the entire tank target is required to be visible than if only 1/2 or 1/4 of the tank is required to be in view to qualify as visible. This has implications for a variety of weapon systems in the definitions of "effective visibility for engagement" as compared to "visibility" defined as any portion of the target available.

(3). These data would indicate that vegetation, not land form, was the cause of most losses of line of sight on Knox types of terrain. Additionally, for the first time, an attempt was made to determine the approximate location of the obstacle causing loss of line of sight.

(4). These data would indicate that attacker tactics have a significant influence on the range to the nearest obstacle causing loss of line of sight. For attackers using "rapid advance" tactics, the majority of intervening obstacles are closer to the firer than to the target. For attackers using "bounding overwatch" tactics, the majority of intervening obstacles are closer to the target than to the firer.

b. Implications.

These results could have significant implications for the battlefield performance of a variety of weapon systems. For example, it is the intervening obstacles close to the firer which have the most impact on line of sight missiles through the effects of "missile shadow" areas. On the other hand, for those missiles homing on reflected laser illumination it is likely that intervening objects which are closer to the target would have more influence.

(1). The target aspect presented by attacking tanks is largely head-on or quartering. It is seldom that a crossing target is presented for engaging gunners.

(2). When comparing the results of film data with that obtained from visual observers, the effects of measurement resolution are significant. The visual observer is not capable of reacting to brief target exposures which would show up in a high resolution film analysis. This also applies to short breaks in line of sight to the target. And yet, with the more sophisticated weapon systems, these short interruptions to line of sight to which the gunner does not react (i.e., subliminal clutter) can have a significant impact on performance.

D. Chinese Eye III

Analysis of Intervisibility Survey of Exercise Chinese Eye III Actions, Stead, C. and Rowland, D., Defense Operational Analysis Establishment Memorandum M 77104, April 1977 (UK-RESTRICTED)

1. INTRODUCTION

a. The Chinese Eye III experiment, a simulated "live-fire" exercise, was conducted in 1975 by the Defense Operational Analysis Establishment of the UK in the British zone of the FRG. The intervisibility portions of these exercises were called Chinese Horizon I (summer experiment) and Chinese Horizon II (winter experiment). The total data package is not available for review at this time.

b. The "intervisibility" data were collected using the "Battelle Walk" method. Data were collected for 6 different sites. There were 4 attack routes and about 6 defender locations selected for each site.

2. CRITIQUE

This experiment was apparently rather well done in that it was conducted under tactically realistic conditions with good measurement control. The following "positive" points are made regarding this experiment:

a. The intervisibility test was conducted after a simulated "live-fire" exercise, i.e., the defender sites and attacker routes were selected as a sub-set of tactical trials to give balance to the general types chosen. Two sites each were selected from so-called plain, rolling, and valleyed types of terrain. These sites are, therefore, not necessarily biased in favor of good visibility.

b. The sites selected, while not necessarily typical of other places even in Germany, are located in a highly probable combat zone.

c. Testing was done under both summer and winter conditions. Thus, intervisibility data for identical locations may be compared for assessment of seasonal variations.

d. The analysis of test results attempted to determine the variation in intervisibility due to a general classification of the terrain (i.e., plain, rolling, or valleyed), the average height differential between the attacker and the defender, and seasonal variation.

The following "negative" points are made:

a. The "Battelle Walker" method was used to record data. This gives an implied intervisibility, but really only measures visibility from the attacker to the defender.

b. The data were collected at 50-meter intervals along each route. Thus, the results are probably not adequate for establishing the existence of problems in the area of subliminal clutter.

3. USES OF RESULTS

Assuming the 50-meter interval is adequate for measurement purposes, the following data are available from this experiment:

a. IV/OOV (in-view/out-of-view) segment lengths for each defender site/attacker route/site location/summer or winter combination. (Available in the UK).

b. The mean and standard deviation, as well as histograms are given for the IV segment lengths. Similar data for OOV segments were also recorded and both are summarized in Table IV-4.

c. The above means are plotted as functions of the average difference between the attacker and defender altitudes. The variation in the mean is highly correlated with this variable.

d. Sightings are also categorized with respect to defender posture, i.e., hull up or hull down.

The following additional analyses are planned by the UK.

a. A determination of the proportion of each attacker's route covered by all defense weapon sites.

b. The distribution of the number of weapon sites having simultaneous line-of-sight to any section of a given route.

c. The proportion of defensive weapon sites having any LOS at all to a given attacker.

d. The ranges at which initial "intervisibility" occurs to any given defender, then to 50% of the defenders.

e. The proportion of the number of attack routes seen from a given defender site.

It is difficult to know whether or not the information gathered about the Chinese Eye sites is transferable to other sites. The UK has, however, given some general classifications which might make this possible.

4. IMPLICATION ON THE DESIGN OF FUTURE EXPERIMENTS

This experiment should be used as an example for selecting attacker/defender positions. The "Battelle Walker" method should not be used for collecting data. Some method of measuring continuous LOS for a variety of sensors is required for future experiments.

E. Lost Horizon

Exposures of Armored Fighting Vehicles, Exercise Lost Horizon, Defense Operational Analysis Establishment Report 7011, June 1971 (UK-CONFIDENTIAL)

The report of the Lost Horizon exercises is classified UK-CONFIDENTIAL although certain items of data from the report are unclassified. Therefore, the summary and critique of the study are contained in the classified annex to this report. Appropriate unclassified data, however, appear in Chapter IV of this basic volume.

F. NATO Range Study

Study to Determine the Maximum Essential Antitank Range Requirement for the Main Armament of the Future Main Battle Tank, SG/ATR WP-1 (AC/174), Annex D, 1963

1. INTRODUCTION (Quoted directly from Reference II-F-1)

"This study conducted a map analysis similar to that of prior BRL studies and discovered that if anything, the intervisibility ranges were on the average shorter than those reported in earlier BRL work. This was then followed by a series of field measurements. As the quotation below will show, the field measurements resulted in much longer average engagement ranges and a much higher frequency of engagements at long ranges.

"'The data sought were the ranges of intervisibility (not detection or engagement) that would occur as the opposing tanks maneuver in meeting, defensive, and offensive operations. The ranges obtained were very much longer than those derived from the map analysis. For example, on the map of the Rodenberg area of Northern Germany, for one of the three areas on which actual field exercises

were conducted, the map games[1] showed a mean intervisibility range of 3556 meters, while the map analysis had shown 714 meters. So far as can be determined, the NATO investigators do not explicitly account for the great differences between map analysis results and map game results. The most likely explanation would seem to be that the map analysis took account of the closest tank-obscuring object only, in randomly-selected, representative areas of each map, while the map games apparently took place on those portions of the map which the players determined most suitable for tank combat. Yet even so, the difference seems greater than would be expected.' "

2. CRITIQUE (Quoted directly from Reference II-F-1)

"Reflection on the differences in procedure makes it clear why these results are different and further makes it clear why the NATO Range Study is a better estimate than any other previous ones. The map analyses and studies that derive from them measure with some precision the distribution of ranges between obstacles that can hide two tanks from each other. However, in the course of a battle, tanks must move from somewhere 'off the map' to positions on the map. The NATO Range Study is, in fact, a measure of the distribution of the distances at which tanks could be seen during this movement. It is therefore a much better estimate of the range dependence of opportunities to engage them in any of the previous studies.

"There are some reasonable criticisms of the NATO Range Study. One is that it does not provide a measure of probabilities of detection given that intervisibility exists. Nor does it measure the probability that the intervisibility to a moving target will be obscured in a time too short to permit engagement after detection. It may, therefore, somewhat overestimate the probability that a successful engagement will be possible as a function of range. On the other hand, it has been criticized because in its selection of positions for the analysis, it used to the extent possible positions that would have been selected by combat units equipped with then current weapons (M60 tanks and 106 recoilless rifles). It has been argued that if forces were equipped with weapons with much longer effective ranges, they would, in fact, be able to select defensive positions that provided even greater intervisibility ranges than those that were considered

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[1]"Map game" refers to sets tactical exercises carried out on a map in the context of a war game wherein attacks against selected objectives were carried out. "Map analysis" involved the random selection on a map of potential attacker routes and defender positions independent of a specific military context. In each case LOS and first sighting distances were estimated from map contour lines and vegetation overlays.

in the NATO Range Study. It is obviously desirable to improve our understanding of this operational problem".

3. USES OF RESULTS

Since this study was the first to include quantitative measures of first sightings of targets at long ranges, and thus provided considerably different ranges than previous studies, a significant methodological contribution to the state of the art was made. In addition, the basic data have provided insights concerning the distribution of closing ranges until first sighting, and after certain manipulations (see Reference II-F-2) have been proposed for use in certain duel models.

4. IMPLICATIONS

Future experiments must take into account possible sightings of attackers beyond weapon range to properly predict first sighting distances and other intervisibility parameters. Serious questions have also been raised concerning the adequacy of map exercises to provide realistic parameter estimates for simulation and analytical studies.

References:

II-F-1: Payne, W. B., Memorandum for Mr. Donald Frederickson, 18 December 1969.

II-F-2: Payne, W. B., Memorandum for Mr. Donald Frederickson, "Range Distribution from NATO Range Study," 20 January 1970.

III DEFINITIONS

The need for a set of definitions became apparent as the various reports were reviewed. Therefore, we are proposing the following in an attempt to clarify the process of engaging targets, to guide experimenters in planning tests and in reporting their findings, and to provide a uniformity of understanding in the terminology used in discussions regarding line of sight and visibility.

In writing these definitions, we have attempted to retain the generally accepted meanings of the terms, but generalizing them somewhat. We have also attempted to define the events leading up to the engagement of a target in such a way that the occurrence of an event is conditional on the occurrence of the more basic events. We have also tried to generalize concepts which, until recently, were used only for visual (eyeball) target acquisition; but currently need to be defined for a variety of sensors, including lasers, radars, as well as the eyeball. With this in mind, the popular term "intervisibility," with its implication of reflexivity, loses all value except as a generic term. Therefore, it does not appear in our list of basic definitions.

The most basic event leading to the acquisition and subsequent attack of a target is the existence of line of sight. We think two kinds of line of sight need to be defined.

> DEFINITION 1: A point is said to be within line of sight of a sensor (or, equivalently, a sensor is said to have line of sight to a point) if and only if the energy to which the sensor reacts can travel from the point to the sensor unobstructed by terrain, vegetation or solid man-made objects. Spurious signal paths created by atypical conditions are not to be termed lines of sight.

This definition does not require that the energy travel in a straight line, but allows it to travel in whatever curved path is appropriate for that kind of energy and for the atmosphere through which it is travelling. With this basic, almost mathematical, definition of line of sight from a sensor to a point, it is possible to define line of sight to an area.

> DEFINITION 2: An area is said to be within line of sight of a sensor (or, equivalently, a sensor is said to have line of

sight to an area) if and only if one or more[1] points in that area are within line of sight of the sensor.

The area to which line of sight may exist by this definition may be a portion (or even all) of the presented area of an object on the battlefield. It may also be an area of the battlefield itself. The definition is not intended to be restrictive. The existence of line of sight to an area does not guarantee that the object will be visible to the sensor. It may be that atmospheric attenuation of the energy or the sensitivity of the sensor itself precludes the receipt of sufficient energy for the sensor to have reacted to the presence of the object.

> DEFINITION 3: Visibility is said to exist from a sensor to an area if (1) line of sight exists from the sensor to the area, and (2) the energy level reaching the sensor from the area is above the sensor's threshold of sensitivity.

Thus, for example, a tank may be visible on a clear day but not on a hazy day, not because line of sight which existed on the clear day does not exist on the hazy day, but because the energy is attenuated so much more by the haze that not enough reaches the sensor to cause the tank to be "seen." Similarly, line of sight may exist to small objects at a long range, but the limitations on the acuity of the sensor may preclude the object being sensed.

This definition of visibility implies that an object which is visible to a sensor is capable of being detected. Whether or not it will be detected depends on a number of factors. Among these are the contrast it makes with the background, its size and shape, and whether it is stationary or moving.

> DEFINITION 4: Detection of an object to which visibility exists takes place when the sensor, or its operator, is alerted to the presence of that object.

A stationary camouflaged tank, for example, may be clearly visible, yet remain undetected because it blends well with its background. In order for such a tank to be detected, some additional clue may be required. For example, if the tank moved, it might immediately be detected.

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[1] There was a strong lack of concensus within the task force on what constituted an "area". As a result, two of the task force members feel that the words "one or more" should be replaced by "a significant number of."

It can be argued that visibility and detection are essentially the same thing, since the only way to test for visib. .ity is to determine if some sensor can detect the object. However, we feel this to be a practical limitation on the obtaining of empirical data rather than a theoretical constraint on the phenomena themselves.

Detection simply alerts the observer to the presence of something of possible military interest that warrants further evaluation.

DEFINITION 5: Recognition of a detected object takes place when it is correctly classified as to its general type on the basis of the sensed information.

When a detected object has been studied long enough and/or is adequately visible to allow a determination that it is, for example, a tank, then recognition has taken place. It is possible that an object may be detected, but not recognized; similarly an object detected in a search for, say, tanks, may subsequently be recognized to be nothing more than a boulder, or a shadow.

DEFINITION 6: Identification of a recognized object takes place when the specific designation of that object is determined to the extent necessary for firing decisions to be made.

Thus it follows that part of identification is the determination of whether the object is friendly or enemy, and so whether it is a potential target or not. As used in this definition, the term firing decisions may include such factors as target priorities and selection of weapons, rounds, and aim points. It does NOT include the decision to actually fire.

As in the relationship between recognition and detection, the relationship between identification and recognition implies that further examination and/or a greater degree of visibility may have to occur in order to allow a refinement in the classification of the object.

The final step in the process is the engagement of the identified target. Whether or not a target will be engaged by a particular weapon will depend on many factors, not all related to line of sight and visibility, such as availability of ammunition and constraints imposed by the tactical mission. Therefore, we will define only the concept of engageability. To do this we first need to define several other terms related to line of sight and visibility.

DEFINITION 7: The first line of sight range is the range from a deployed sensor at which the target first comes

within line of sight of that sensor.

DEFINITION 8: The first visibility range is the range from a deployed sensor at which the target is first visible to that sensor.

The typical situation is that in which a target is closing on an observer or vice versa, so that the first line of sight range (or first visibility range) is the longest range at which line of sight (or visibility) occurs. These two definitions, however, do not imply that that must be the case. The term "first" here means first in time, or earliest. They also do not imply that line of sight (or visibility) are continuous subsequent to this earliest time at which they occur.

DEFINITION 9: A visible path segment is a portion of the path a moving target is taking over which target visibility is continuous to the sensor being considered.

In keeping with the previous definition of visibility, this implies that on each part of the path segment only some point on the moving target may vary with time. Furthermore, this definition does not mean to imply that there is only one such segment on a given target path; there may, in fact, be several

DEFINITION 10: A nonvisible path segment is a portion of the path a moving target is taking over which target non-visibility is continuous to the sensor being considered.

Clearly, then, the path of a moving target is composed of an alternating pattern of visible and nonvisible segments. Possibly of more tactical significance than these segments themselves are the duration of time a target is on each type of segment.

DEFINITION 11: A visible time segment is the length of time a target is on a visible path segment.

DEFINITION 12: A nonvisible time segment is the length of time a target is on a nonvisible path segment.

Time is then composed of an alternating pattern of visible and nonvisible time segments. Note that while the concepts of visible and nonvisible path segments apply only to moving targets, the concepts of visible and nonvisible time segments apply as well to stationary targets as viewed by moving sensors.

It is possible to write definitions similar to 9 through 12 substituting "line of sight" for "visibility." However, such definitions would be primarily of academic interest, since some pattern of projected future visibility (as opposed to just line of

sight) is required to determine the engagement of an already identified target.

DEFINITION 13: A visibility pattern for a target is any set of alternating visible and nonvisible path or time segments for that target.

A particular visibility pattern would be identified by the lengths, in either distance or time, of the segments comprising the pattern, and the order in which they appear. Two visibility patterns would be identical only if they were composed of segments of the same length (or duration) occurring in the same order.

These definitions allow for the final definition, that of engageability.

DEFINITION 14: An identified target is engageable by a weapon if its future visibility pattern does not preclude successful employment of that weapon.

A target may be engageable by one weapon and not another. For example, a tank that is visible for only a short period of time may be engageable by a high-velocity tank gun, but not by TOW. The definition, however, is not meant to imply that continuous visibility of some duration is required. Certain weapon systems may be able to achieve a normal hit capability even if the target visibility pattern consists of intermittent visible and nonvisible segments. For such a weapon and visibility pattern, then, the target would be engageable.

IV DATA SUMMARY AND ANALYSIS

A. Background

Among the factors which led to the appointment of the Terrain Task Force were conflicting results among several studies involving such factors as first sighting range and the means and variations of the lengths of path segments in which an attacker was in-view (IV) and out-of-view (OOV) of one or more defender sites. The Task Force, therefore, examined each of the six experiments discussed in Chapter II to determine the values obtained for each of these factors of interest.

Unfortunately, not all of the exercises had been designed to measure each of the factors, so it was not possible to get complete sets of information. All data which were obtained are tabulated in the next section of this chapter. These tables represent the data set available for comparison of the various field trials. The items included (where available) are:

Site ID - An identifier associated with a particular trial of the given experiment, e.g., TETAM Site 1F.

Average Number of Segments per Path (IV and OOV) - The number of segments per path in-view (IV) gives the number of times LOS was initiated along the path on the average; likewise, for out-of-view (OOV), the number of segments per path denotes the number of times LOS was broken on the average.

Mean Segment Length (IV and OOV) - The mean length per in-view path segment (i.e., in-view implies all points along a path segment are assumed to be in-view of an observer) and the mean length per out-of-view segments in meters.

Standard Deviation (IV and OOV) - Standard deviations for the previously defined quantities.

Probability of LOS for Range (1000 meters, 2000 meters, and 3000 meters) - An estimate of the probability that a target would be in-view of an observer at that range for that particular terrain site.

Number of Observers - The number of observers (defender sites) used in the trial.

Number of Paths - The number of trails (often attacker routes) used in the trial.

First Opening Range - An estimate of the expected range where a target would first appear to an observer for each particular terrain site.

Expected Opening Range - An estimate of the expected range where a target would appear visible to an observer (possibly a subsequent siting) for each particular terrain site.

Average Path Length - The mean of all the paths used in a particular trial.

Since all or portions of TETAM, Chinese Eye III, Lost Horizon, and the NATO Range Study were conducted in the Federal Republic of Germany, the locations of each trial are indicated on a map of the area in Figure IV-1.

B. Data Summary

The data described in Section IV-A are given for each of the six field trials wherever data were available. Sources of data and pertinent comments are given as footnotes for each table.

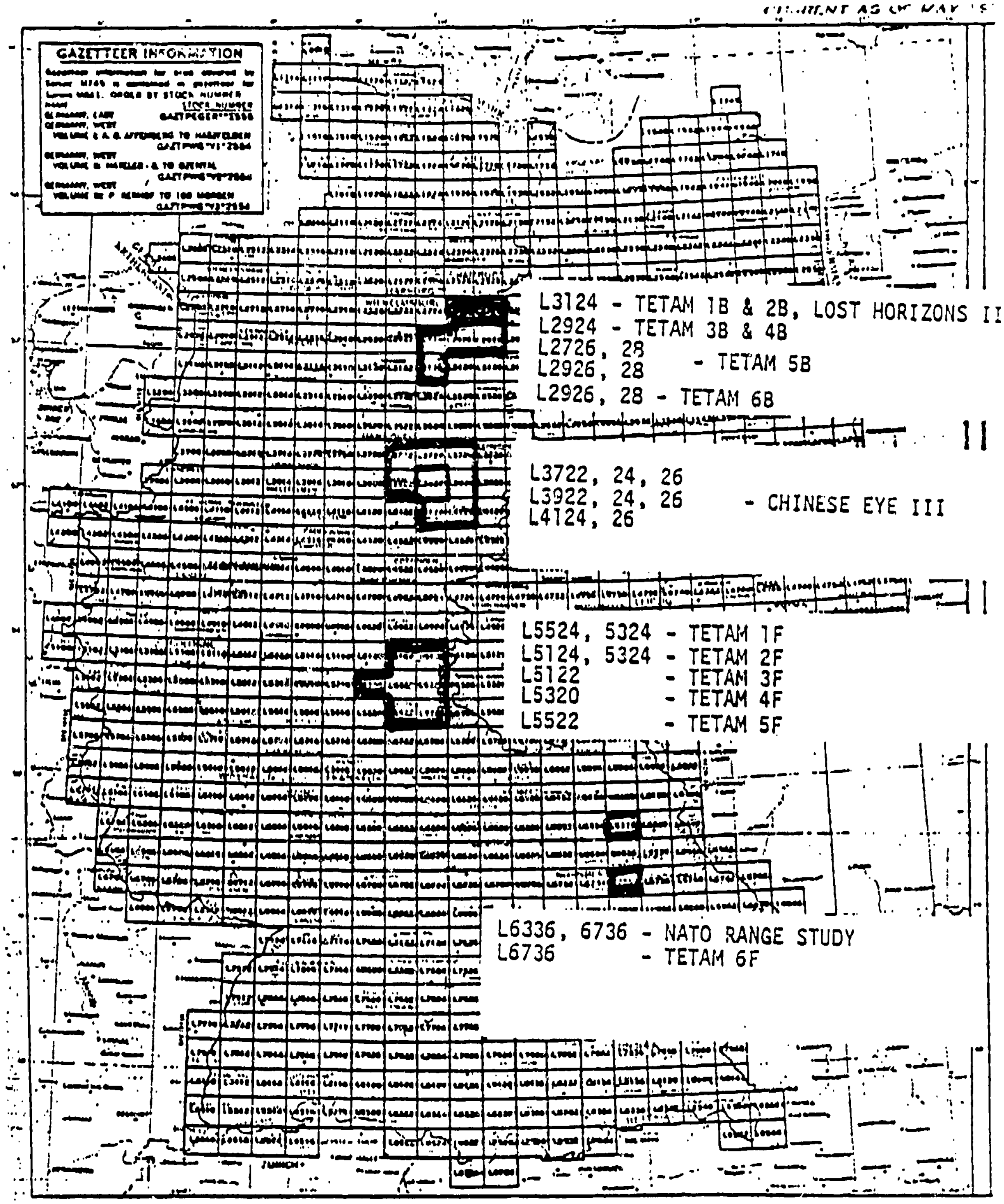

Figure IV-1. Locations of field trials in the FRG.

Table IV-1

TETAM INTERVISIBILITY DATA

SITE ID	Average Segments per Path[1] IV	No. of Segments per Path[1] OOY	MEAN[1] Segment Length(m) IV	MEAN[1] Segment Length(m) OOY	Standard[1] Deviation(m) IV	Standard[1] Deviation(m) OOY	Probability of LOS[2] for Range(m) 1000	Probability of LOS[2] for Range(m) 2000	Probability of LOS[2] for Range(m) 3000	No. of[1] Observers	No. of[1] Paths	First[1,3] Opening Range(m)	Expected[1,3] Opening Range(m)	Average[4] Path Length(m)
1F	4.0	3.2	247	264	251	429	.30	.34	.30	36	10	2604	1677	2963
2F	3.6	3.8	385	365	419	369	.65	.38	.29	36	9			3764
3F	3.4	3.3	298	242	235	314	.46	.30	.19	30	10			3893
4F	2.9	2.4	388	591	377	704	.64	.16	.31	36	9			4583
5F	2.2	1.9	208	214	236	268	.35	.16	.01	36	10	1625	1332	2240
6F	3.2	2.9	267	160	337	316	.52	.18	.20	30	10	1445	1358	2948
1B	5.4	5.1	119	315	164	485	.16	.27	.06	30	10	2914	1888	4028
2B	5.1	4.7	209	291	277	383	.57	.30	.18	36	10			3418
3B	3.9	3.5	124	176	160	312	.35	.03	.01	30	10	1391	916	3648
4B	2.4	1.8	60	63	64	78	.13	.00	.00	36	10			2870
5B	1.2	.6	176	113	157	98	.19	.00	.00	36	10			1940
6B	2.8	2.1	96	296	140	366	.18	.02	.00	36	10			1624

Notes/References:

1. D. H. McCoy, Analysis of the TETAM Phase IE data tapes(Unclassified)
2. Tactical Effectiveness of Antitank Missiles(USACDEC Experiment 11.8, TETAM), Vol II, Phase IE, October 1972(Unclassified)
3. Incomplete stake data does not allow completion of these columns at this time.
4. "Report on TETAM Intervisibility Data," Michael Hoffman, AORS XV Proceedings Vol 2, TRADOC, October 1976(Unclassified)

Table IV-2

HELAST II INTERVISIBILITY DATA[1]

SITE ID	Average Segments per Path[2] IV	No. of Segments per Path[2] OOV	MEAN[2] Segment Length(m) IV	MEAN[2] Segment Length(m) OOV	Standard Deviation(m)[2] IV	Standard Deviation(m)[2] OOV	Probability of LOS[2]	No. of Observers[3]	No. of Paths[4]	First Opening Range(m)[5]	Expected Opening Range(m)[5]	Average Path Length(m)[2,6]
Composite of all Trials	3.0	3.8	32	37	45	39	.41	38	25			237

Notes/References:

1. A. J. Eckles, et al, HELAST II, July 1973(Unclassified).
2. D. H. McCoy, Analysis of the HELAST II data base(Unclassified).
3. There were about 5 observers per course.
4. There were 7 courses with 1 to 5 segments each.
5. These numbers were not computed.
6. The number is an estimate. The actual number is probably slightly greater.

Table IV-3

STAGS INTERVISIBILITY DATA[1]

SITE ID	Average Segments per Path[2]		MEAN[3] Segment Length(m)		Standard[3] Deviation(m)		Probability of LOS[4]	No. of[5] Observers	No. of[6] Paths	First[7] Opening Range(m)	Expected[7] Opening Range(m)	Average[8] Path Length(m)
	IV	OOV	IV	OOV	IV	OOV						
Knox 1												
Rapid Advance												
Visual	7.6	7.9	123	52	205	102	.69	10	5			1525
Laser	38.9	39.1	26	11	85	32	.70	5	5			
Overwatch												
Visual	10.8	11.1	45	64	73	166	.41	10	5			1439
Laser	53.0	53.5	10	16	27	60	.38	5	5			
Knox 2												
Rapid Advance												
Visual	7.0	7.3	96	90	153	209	.51	10	5			1331
Laser	16.1	16.3	21	51	68	171	.29	5	5			
Overwatch												
Visual	8.9	9.3	57	112	67	223	.33	10	5			1441
Laser	24.5	24.7	14	41	29	152	.25	5	5			
Bliss 1												
Rapid Advance												
Visual	3.8	3.8	367	180	597	344	.67	9	5			2930
Laser	9.4	9.7	144	42	466	144	.77	6	5			
Overwatch												
Visual	8.7	9.3	220	135	424	355	.60	9	5			3380
Laser	14.6	15.3	145	56	47[illegible]	189	.71	5	5			
Bliss 2												
Rapid Advance												
Visual	10.7	11.3	331	153	681	419	.67	9	5			4355
Laser	47.5	48.0	63	42	217	187	.60	6	5			

Table IV-3

STAGS INTERVISIBILITY DATA[1] (cont'd)

SITE ID	Average No. of[2] Segments per Path IV	OOV	MEAN[3] Segment Length(m) IV	OOV	Standard[3] Deviation(m) IV	OOV	Probability of LOS[4]	No. of[5] Observers	No. of[6] Paths	First[7] Opening Range(m)	Expected[7] Opening Range(m)	Average[8] Path Length(m)
Overwatch												4525
Visual	8.5	8.6	328	193	617	450	.63	9	5			
Laser	31.9	32.0	81	49	230	194	.62	5	5			

Notes/References:

1. A. J. Eckles, et al, The Influence of Tactics, Use of Terrain, and Measurement Techniques on Apparent Target Behavior, TM 23-77, July 1977.
2. Estimated from Tables 6 and 8 of the above reference.
3. Copied from Table 8 of the reference.
4. Estimated from the data in Table 8 of the reference.
5. Gathered from Table 1 of the reference.
6. Collected from Table 3 of the reference.
7. These Data are not presently available.
8. Calculated from Table 4 of the reference.

Table IV-4

Chinese Eye III Intervisibility Data

The data from Chinese Eye III included in Table IV-4 are classified UK-RESTRICTED. Therefore, the table, which includes only site identification, average number of IV segments per path, the mean length of IV and OOV segments, and probability of LOS, is contained in the classified annex to this report.

Table IV-5

Lost Horizon Intervisibility Data
(and comparison with TETAM)

Site ID	Mean IV Segment Lenth (M)
Lost Horizon[1]	
Site A	400
Site B	475
TETAM Composit[2]	326

1. Exposures of Armoured Fighting Vehicles, Exercise LOST HORIZON, J. P. Wood, R7001, March 1971. (CONFIDENTIAL)

2. TETAM EFFECTIVENESS EVALUATION, Part 1, CACDA, TM 2-73, 16 November 1973. (UNCLASSIFIED). Note the variation in experimental results between the LOST HORIZON data and these TETAM results from tests run on essentially the same piece of terrain.

Table IV-6

NATO Range Study Intervisibility Data

SITE ID	Mean Segment Length(M)[1]
Composite of 3 Sites	413 - 219[1]
Composite of 3 Sites	385[2]

1. Target/Range Experience for Tank and Antitank Weapons, T. N. Dupuy, HERO, November 1967. (SECR [illegible]).

2. TETAM EFFECTIVENESS EVALUATION, Part 1, CACDA, TM 2-73, 16 November 1973. (UNCLASSIFIED)

C. Discussion

The material presented in Chapter II indicated significant differences in objective, experimental design, definitions of terms, experimental method, data collection, and data analysis, any one of which could cause differences in the values obtained for any of the data reported. It should be no surprise, therefore, that even though several of the trials involved similar terrain, radically different results were obtained.

In the case of measurements of the lengths of IV and OOV segments, differences in the results among studies is even less surprising when one observes the magnitude of the standard deviations of these lengths within studies. In all cases the means and standard deviations are of the same order of magnitude and in the majority of cases the standard deviations exceed the associated mean value. This could cause large inter-study differences in the mean lengths but at the same time mask the significance of these differences were formal statistical testing performed.

Although the effects of definition, procedure, etc., for each exercise has been discussed in some detail in the appropriate sections of Chapter II, a few specific items will be noted here. First is the probable effect of the definition of what was called "intervisibility" in the TETAM study where each observer was required to make a judgment as to whether there was sufficient clearance to allow him to engage the target. This would tend to cause one to believe that the average segment lengths obtained in TETAM might be shorter if some other definition (or means of measurement) had been used. Still, in general, the TETAM path lengths were longer than those in HELAST II and STAGS, probably due to resolution differences and the way in which extremely short interruptions in LOS were handled. The very low average lengths found in HELAST II could well be due to the relatively short total lengths of the paths used.

In addition to these fairly obvious causes of differing results, there could also be some additional items which are not so easily interpreted. A plot of the results of three independent analyses of the same TETAM field data from each of the 12 FRG sites show large differences, particularly for sites 2F, 4F, 5F, 6F, and 5B. Although no formal statistical tests have been run to determine whether these differences are significant, considering the large sample sizes involved, there is a good chance that they are.

Another example of a possible cause for concern is the contradiction one discovers when comparing the mean in-view segment lengths from TETAM 1B and 2B (Table IV-7) with those from Lost Horizon II (Table IV-5). If lack of measurement resolution generally causes in-view estimates to be long, then by all rights, the TETAM (25 meter resolution) lengths should be greater than Lost Horizon II (continuous resolution) lengths. They clearly are not. The contradiction between these experimental results remains unexplained.

Table IV-7

Mean In-View Segment Length

TETAM		Lost Horizon II	
1B	2B	Site A	Site B
119	209	400	475

D. Suggestions for Additional Data Analysis

In light of the concerns just pointed out, it is strongly recommended that the following be done:

1. That the TETAM data be completely reduced using the latest version of the "sanitized" BDM data tape.

2. That a computer experiment of TETAM be conducted using the DMA data base.

3. That the Chinese Eye III data base be reduced to fill in Table IV-4.

4. That the raw data for Lost Horizon II be obtained from the UK and reduced and recompared with TETAM 1B and 2B.

V IMPLICATIONS ON WEAPON SYSTEMS ANALYSIS

A. Introduction

Several of the studies which provide the Army's current LOS/visibility data base have been reviewed in Chapter II and the basic data summarized in Chapter IV. These data are of great importance in guiding the concept, design, and development of materiel and associated tactics, and in the final evaluation of system capability. With these primary uses in mind, it is the purpose of this chapter to assess the current status of our LOS/"visibility" data base and suggest areas where some confidence is warranted and others where more work is required. Thoughts on "visibility" tests, the associated data collection, and system evaluation methodology are also presented.

B. Discussion

Army systems have various requirements with respect to the existence of line-of-sight. In this section the intent is to discuss (1) three generic systems, (2) the line-of-sight characteristics required for the proper functioning of each, (3) how each interacts with the terrain and vegetation to obtain this line-of-sight, (4) what characteristics of the terrain and vegetation are required to model the functioning of each, and (5) the adequacy of the current data base in providing measures for these characteristics.

The first and simplest system is the high velocity direct fire weapon, such as a tank gun. In the normal firing mode, such a system requires that a target be visible at the time the projectile is launched, (in order to be able to aim) and that the projectile path be unobstructed. Since this is a "fire and forget" type system, it does not matter if the target passes behind a tree or other obstruction momentarily as long as the projectile path itself is not obstructed by an object it cannot penetrate with little or no loss of energy. This point-to-point line of sight is exactly the type measured and reported in the current field exercise data base; and, therefore, these data are felt to be adequate for the assessment of direct-fire systems. Unlike the guided systems to be discussed in the following paragraphs, the location of obstacles along the weapon-target line is not important for the evaluation of direct fire weapons; only knowledge of the existence and ruggedness of such obstacles is important.

The second system type is the line-of-sight guided missile, which essentially flies along the line of sight from the launcher to the target. The TOW missile is an example of this system type. During missile flight, the gunner simply keeps his crosshairs on the target. The missile has a flare which is visible to a sensor on the launcher, and the displacement of this flare relative to the line of

sight determines the guidance corrections imparted to the missile. If line-of-sight to the target is momentarily interrupted in such a way that the gunner can anticipate the reappearance of the target, no loss of effectiveness may occur unless line-of-sight from the tracker to the missile flare is interrupted. The missile will abort if this line-of-sight is broken for a sufficient period. The current data base is inadequate for the evaluation of systems of this type if a significant number of engagements are expected in other than totally open terrain.

The third system type is the terminal homing projectile/missile requiring laser designation of the target. Such a system requires the target to be essentially continuously visible to the designator during the last several seconds of the projectile flight so that the designator operator can keep the laser spot on the target. This requirement implies that a certain duration of visibility must exist, and several of the field tests have developed data which allow the estimation of the probability that LOS will exist for the needed duration. However, other parts of the problem have not been addressed. The designator operator may have continuous visual line-of-sight to a target in the sense that he can see some part of that target, follow its progress, and think that he is designating it. If, however, the laser beam is momentarily interrupted by a branch, leaf or tree trunk as the target passes behind such small obstructions, the seeker could pick up and be guided by these false target reflections or "decorrelate: due to a loss of signal. Nowhere in the current data base are there measurements of the presence and location of such possible false targets, although STAGS did allude to their possible presence. (This may be noted to be quite similar to the data required for the evaluation of TOW type missiles).

Another part of the laser designator/seeker problem is the visibility link between the target and incoming projectile seeker. The current data base contains no information concerning the existence of line-of-sight along this path, even though this area appears as important to system performance as the link between designator and target.

C. Thoughts on Test Structuring and Data Collection

This section discusses the lessons we have learned from our review of previous visibility tests and guidelines which may be useful for future experimental efforts.

1. OFFENSIVE-DEFENSIVE LOCATIONS

The weapon and vehicle positions/paths chosen must make the best tactical use of the available terrain, but must be realistic as well. That is, defender positions should not be chosen which maximize the visibility of avenues of approach while neglecting all consider-

ation of escape routes and/or cover and concealment. Similarly, attack paths should not be chosen individually, but as part of the coordinated movement of a reasonable sized force and thus be dependent upon the tactics involved, i.e., rapid advance, bounding overwatch, etc.

2. MULTIPLE TARGET VISIBILITY

Of the six studies reviewed, only STAGS (and perhaps Chinese Eye) describe, as a function of time, the number of targets visible to each defender and the number of defenders which can view each target, i.e., multiple target visibility data. These data could be quite valuable in the evaluation of weapons with rather long times between firing and impact, such as TOW and even to a larger degree COPPERHEAD and HELLFIRE. For these systems, the target for which the weapon was originally intended may no longer be visible at the time the weapon arrives in the vicinity. If however, another candidate target can be found within the remaining maneuver capabilities of the already launched weapon, the weapon may be able to be redirected to the second target. Waterways Experiment Station (WES) has conducted experiments regarding both (1) multiple observers and a single target and (2) a single observer and multiple targets, but the results are as yet unpublished. In addition, some analytical effort has been undertaken in this area by AMSAA, in support of the evaluation of COPPERHEAD. It may be informative to see how the results of this work by AMSAA compare with those obtained by WES and the data from STAGS and any other appropriate field studies.

3. NEED FOR REPLICATION

Experimental set-ups should be structured to provide the data that are really needed for system evaluations. For example, f. a given engagement location, attacker and defender forces, and tactics, the objective of an experiment should be to estimate LOS or appropriate visibility parameters (e.g., the probability of the existance of LOS as a function of range and/or the distribution of segment lengths for which attackers are within view of defenders) which will, on the average, occur. That is, different commanders would not choose exactly the same defender positions or attack paths and previous field and analytical studies have shown that the changes in LOS statistics, for even minor changes in position, can be large. Therefore, it cannot be assumed that the results from a single replication of an exercise, on one piece of terrain, will produce results which are representative of those from a large number of trials. Replication of field exercises is expensive and time consuming. However, unless such exercises can be repeated, or digitized data for the terrain exist which are sufficiently detailed

so that the operation can be replicated on the computer, little faith in the results may be warranted. This situation has undoubtedly contributed to the variability found among the results of existing studies.

4. LOS MISSILES AND LASER-GUIDED WEAPONS

Based upon the findings discussed in the previous section of this chapter, it appears that the biggest data gap exists for LOS missiles and laser guided weapons due primarily to the coarseness with which visibility data have been collected in many previous studies. In fact, these systems are most sensitive to the very short duration breaks in visibility, and their ultimate performance depends upon the type of object causing the obstruction and its location with respect to the designator/target/seeker geometry. In fact, these data have not been obtained in any test, except to a limited extent through the HEL post-test analysis of film data collected during the STAGS tests (discussed in Chapter II). As more and more data are required for the realistic evaluation of systems, the time and cost associated with field testing grow drastically, especially in light of the need identified above for the replication of such tests. Further, as mentioned previously with regard to laser guided weapons, no data exist which describe the LOS conditions between the target and incoming seeker. This may or may not be of importance. The physical collection of these data, with the accuracy required, would seem to be quite difficult and time consuming.

An aspect of target visibility analysis which has not yet been examined, but directly affects the operation of LOS missiles and laser guided weapons, deals with the possible effects which could result if fractional cover is highly correlated. The question focuses on the location of masking vegetation along target approach routes, particularly along those path segments where partial target obscuration occurs. In general, the path segments measured in the various studies contain many short periods of partial or complete target nonvisibility. If these breaks are located between correspondingly small visible segments, then these path regions may contain most of the short segments in the overall distribution. Correspondingly, the longer measured breaks would contain relatively little clutter. The net result of this postulated correlated clutter would be to reduce the impact of measurement resolution in estimating the total number of long uninterrupted visible segments and hence the determination of weapon effectiveness. In simpler terms the paths could be classified into three distinct categories: (1) the mostly visible with little clutter, (2) the entirely masked, and (3) the intermittently masked regions. The intermittent region would contribute a large number of small segments in a cluttered/vegetation environment, but the longer uncluttered paths would occur in the mostly visible regions. The above correlation effects, where present, would tend to substantiate the validity of existing data

which show long uninterrupted visible paths. A limited effort at CDEC addressed this effect and some preliminary work is underway at CACDA. A conclusive analysis is badly needed.

5. ADVISABILITY OF FURTHER TESTING

Based upon the perceived need for replication in field exercises and the uncertainty of the other locations to which the resulting data could be applied, the desirability of further LOS or visibility testing seems, at this time, questionable. That is, until it is determined that terrain, including consideration of its tactical use, can be classified according to its visibility characteristics, the widespread applicability of any test results obtained would be in serious doubt. Instead, what testing is done should be directed to solving this terrain characterization problem. In fact this should probably be the highest priority effort in future terrain analyses work, for success in this area has important implications relative to where future visibility oriented field trials are run and in the design of simulation models and war games. As an example, there would be no need to run field trials in foreign countries if terrain with the same or similar "visibility characteristics" could be found in the United States. Unfortunately, at present we do not know enough about terrains to even define adequate descriptors for them.

D. Evaluation Methodology Considerations

Several points have arisen during the work of the Task Force which are pertinent to the evaluation methodology used for specific systems. These are outlined in the following paragraphs.

Computerized wargame simulations such as AMSWAG, TRACOM, CARMONETTE and DYNTACS are commonly used in the evaluation of Army systems and/or doctrinal changes. The tactics of the simulated battle are constructed to take realistic advantage of terrain being used. Digitized terrain data, of the type provided by DMA, are commonly used to determine the existence of LOS between adversaries during the course of the battle. However, it is not uncommon for attacker approach paths and defender positions to be fixed, or fully defined for the entire engagement. This again raises the issue of the variability of results, e.g., exchange ratios and final outcome, due to small changes in participant position which result in significant changes in LOS characteristics. This implies a need for replication in the running of such models, the variation being introduced by alternative, equally realistic placing of defender positions and attacker paths.

Further, while DMA data may be adequate for the assessment of tank gun type direct fire weapons, they are not appropriate for the TOW type systems, which have become such an integral part of the Army's anti-armor capability. Assumptions will have to be made

concerning the degradation of, say, TOW's capability due to the inadequacy of the digitized terrain data which have only a coarse representation of vegetation and very little involving man-made objects.

Finally, as mentioned previously, the widespread applicability of the results of such simulations is in doubt because of our lack of knowledge on the frequency of occurrence of the type of terrain on which the game has been played. Again, we reiterate the need for work on a procedure/methodology for characterizing terrain. Without the results of such a study, the conclusions drawn from any evaluation would seem subject to question.

There has recently been a call within the Army to pay closer attention to the representation of realistic battlefield conditions in system and force evaluations. This may be especially true in the "visibility" area. That is, the existence of LOS as determined from DMA type data, has in the past been synonomous with the existence of what has been called "intervisibility". While LOS is a prerequisite for the existence of "visibility" as defined in Chapter III of this report, the former is not a sufficient condition for the existence of the latter. Some method must be devised for estimating the probability that visibility occurs, given that LOS exists, for specific ranges and battlefield conditions including smoke, dust, weather, and the effects of preparation fires by artillery and the deployment of air-to-ground weapons. When such relationships are derived and incorporated into the combat models, realistic assessments can be made.

Finally, terrain data of a rather coarse nature is usually input into combat models due to the large amount of storage such data require. Several "intervisibility" studies, however, have shown that LOS statistics can change drastically with the resolution at which measurements are obtained. The same finding may also apply to wargames played on digitized terrain. The effect of grid size on predicted LOS is not fully known. The question "How small a grid size is required?" cannot really be answered in general, since it is terrain and perhaps system-dependent.

Sensitivity analyses might be conducted to investigate the grid size problem. The machine storage problems associated with a requirement for small grid size might dictate the development of a response surface representation of the terrain on which the battle is simulated. This would greatly reduce the storage requirement. Further, in order to increase the reality of the simulation, a vegetation overlay, perhaps statistical in nature, could be developed and utilized in the evaluation of the guided weapons. Work such as that being done at CACDA on the correlation between the characteristics of in-view and out-of-view segments could be a part of this statistical overlay.

An additional issue which often arises when considering the use of simulation models, is whether the terrain used in the simulation should represent a section of real terrain or be synthesized to contain combinations of characteristics most appropriate for the objectives of the study involved. Use of such "idealized" terrain certainly holds some potential for enhancing experimental efficiency, but until we know enough about terrain to characterize it and to devise measures for the characteristics, there is no viable way to determine what is "ideal" for any given study. The Task Force feels strongly that our major effort should be to study real terrains to learn how to describe them and how terrain can and should be used militarily. Once a classification system is devised, synthetic terrains can be developed and tested against the characteristics of real terrain to determine what role, if any, they might advantageously play.

E. Conclusion

Many of the suggestions made herein would require a significant amount of effort, and therefore might take considerable time to implement. However, their acceptance should provide a significant improvement in the credibility and accuracy of Army studies and in the capabilities and effectiveness of the material of the future.

VI CONCLUSIONS AND RECOMMENDATIONS

A. Introduction

This chapter presents a summary of what the Task Force feels are the major conclusions we have reached in the process of our analysis and discussions and our recommendations for additional study. All of the items included here have been discussed in detail in the Critique, Uses of Results, and Implications portions of the six study reviews in Chapter II. Most were further developed and supported in Chapter V in the context of weapon systems analysis.

Anyone reasonably familiar with the visibility aspects of miltary weapons systems analysis could, by skipping the rest of the report and reading only this chapter, get a general picture of the steps which the Task Force feels should be followed in the visibility-terrain interaction area. However, it is felt that a full understanding of the motivation, justification, and importance of these conclusions and recommendations can be obtained only after following the process we used to reach them. Therefore, it is strongly suggested that the entire report be read in the order in which the material is presented.

B. Conclusions

1. The widely differing results obtained by many of the previous intervisibility studies have resulted in part from:

(a) the differences in study objectives which dictated a variety of experimental designs and tactical situations,

(b) a lack of adherence to uniform and precise definitions of terms in the "intervisibility" area in general, and, in particular, those related to the characteristics actually measured in the various experiments,

(c) differences in the terrain on which the experiments were conducted, and

(d) the various methods of analysis and assumptions applied in those analyses.

2. Although quantative data are extremely dependent upon tactics and terrain, the available results do demonstrate the existence of tactical terrain areas which present significant target visibility opportunities (40-60 seconds) at ranges of 2 to 4 km against an ad-

vancing armor attack force in a "clear" battlefield environment (i.e., neglecting the masking effects of smoke, dust, etc.).

3. An "intervisibility" data base, adequate for the evaluation of laser systems such as LTD, GLLD, MULE, COPPERHEAD and HELLFIRE, does not exist. The evaluation of these systems requires visibility data between the designator and target as well as between the target and the seeker on the incoming weapon. While no adequate data appears to be available for either segment of the energy path, that corresponding to the segment between target and seeker would appear to be very difficult and expensive to obtain. The current data base is felt to be adequate for high velocity direct fire weapons.

4. The present data bases are not sufficient to determine whether or not subliminal clutter is a real problem for more sophisticated weapon systems. We do not believe there is a real problem in open regions such as Fulda, where LOS is blocked mostly by landforms. However, for those regions such as the North German Plains where vegetation is most often the cause for LOS loss, we cannot now assess the impact that subliminal clutter will have on weapon-system performance.

5. The sensitivity of laser system effectiveness to short breaks in the LOS between designator and target, or target and seeker, affects the meaningful use of the standard, digitized terrain in the wargame/simulation evaluation of those systems. It is felt that, in particular, a finer resolution representation (perhaps statistical in nature) will be required to adequately represent micro terrain features.

6. It is essential that major effort be expended to study terrain and its tactical use for the purpose of gaining sufficient understanding to meaningfully classify terrains as to their visibility characteristics. The usefulness of additional LOS or visibility testing at this time for any other purpose is extremely questionable.

7. The degree of tactical realism in the design and carrying out of field exercises has a tremendous influence on the outcome and, therefore, on both the viability and acceptance of the results. The proper treatment of factors such as (1) the location and tactics of offensive and defensive forces, (2) interactions among members of each force, (3) the method, direction, and resolution of visibility measurements, and (4) the effects of smoke, dust, weather, and preparation fires by artillery and air-to-ground weapons are felt to be extremely important (see Chapter V). STAGS and Chinese Eye III are currently the most successful relative to (1) and (2) and to some extent (3). No study that we know of has addressed (4).

8. Data are required to describe the dynamic relationships among groups of attackers and the resulting in-view and out-of-view path

segments between each attacker and each defensive position in order to determine the probability of redirecting a guided weapon from one target to another. Of the studies reviewed, only STAGS was designed so that this information could be obtained.

9. The replication of field exercises on the same piece of terrain by different sets of forces is required to realistically assess the variability present in the quantities being measured.

10. The potential effects of correlations between the lengths of IV and OOV segments in attack paths require that more knowledge of such correlations be obtained. Some data already exist which could yield this type of information and hence at least some insight regarding the significance of these effects.

11. The variations among the various analyses of some of the TETAM data (see Chapter IV) appear significant enough to warrant further study of these data to attempt to resolve the differences.

C. Recommendations

1. A standard set of precise definitions of terms in the "intervisibility" area should be adopted and adhered to in all future terrain-related studies. Those presented in Chapter III of this report are suggested for consideration.

2. Effort should be expended to develop a method which would be capable of characterizing the LOS characteristics of terrain and more adequately considers all aspects of military use of terrain and its impact on weapons system performance. It is clear that we cannot test on every piece of terrain in which we would be interested. Therefore, estimation of LOS characteristics from certain map or digitized terrain parameters by analytic methods should be undertaken.

3. In light of the problems associated with a subjective terrain classification, and the amount of time required to even attempt an analytical characterization method; any further testing should have as a major objective the development of the classification scheme mentioned in recommendation No. 2 above.

4. A conclusion reached in several IV studies (Lost Horizon, HELAST II) was that LOS characteristics can change drastically when defender positions are changed minimally. A result of a Vector Research Incorporated study showed that similar scenarios played on different pieces of terrain, chosen to be a priori equivalent, can vary widely. Hence in any future experimental effort replications should be performed, even within the same piece of terrain.

5. In light of the results mentioned in 4 above, the adequacy of computerized simulations or wargames - which make use of digitized terrain to determine line of sight - deterministically - must be carefully controlled. That is, decisions should not be based upon the results of a study which play a very small number of scenario/terrain/player position combinations. Care must be taken, through replication of runs on various terrains or in which defender positions and attack paths are varied, to ensure that some concept of outcome variability is evident to the decision maker.

6. To improve tactical realism:

a. All defender visibility determinations should be made from the defender positions toward the advancing units,

b. Threat element paths should be planned as a tactical unit and movement of targets along the paths measured simultaneously. This will also permit the calculation of multiple force visibility statistics,

c. In picking defender positions, consideration should be given to escape routes and cover and concealment as well as visibility of potential avenues of approach, and

d. Effects on the battlefield of smoke, dust, weather, and preparation fires by artillery and air-to-ground weapons should be included.

7. Deviations from tactical realism in field-exercise designs should be made only after studies have shown the deviations make no significant differences in outcome or a means of calibrating the outcomes to conform to those that would have been obtained by more realistic designs is available.

8. Continuous or high resolution measurements of in-view and out-of-view terrain statistics should be made until such time as the resolution of discrete methods required for adequate representation of continuous data can be determined as a function of terrain and weapon types.

9. Effects of intermittent, possibly subliminal, clutter on the performance of various weapon systems must be investigated.

10. Analysis of the CACDA HELLFIRE data for correlations between the lengths of IV and OOV path segments should be completed as soon as possible. Should the results prove interesting, extensions should be made to other terrains by inclusion in future studies.

11. Resources should be made available for further analysis of the TETAM Phase IE and perhaps other TETAM data tapes to attempt to determine the causes of variation among the CACDA, TRASANA, and BDM analyses.

12. A request should be made to the British DOAE for additional analysis of the Chinese Eye III data to permit expansion of the visibility data in Table IV-4 to the same format and degree of completion as the TETAM and STAGS tables (Tables IV-I and IV-3).

13. Attempts should be made to develop analytic models for the performance of TOW, Beamrider, and other missile systems involving guidance or target designation by EO means. Success in this venture could reduce the amount of field testing of such systems and could in addition facilitate computer simulation studies in which they are involved.

14. Initiate a research effort to develop a method for statistical comparison of the results from analytic studies with those of field exercises.

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Appendix A

The Army Terrain Task Force - List of Members

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Appendix B

Initial Information Sources for Terrain Task Force

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